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National Report

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2025: SOFT ENERGY FUTURES FOR CANADA

Volume I: National Report

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February 1983

Prepared as part of the Friends of the Earth Soft Energy Path Study for the Department of Energy, Mines & Resources and Environment Canada.

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PREFACE

The term "soft energy path" and the organization "Friends of the Earth" have been associated from the start. It was Amory Lovins, then U.K. Representative of Friends of the Earth, who coined the term in the mid-1970s and who developed the method of analysis used in soft energy path studies. By and large, it has been analysts associated with Friends of the Earth groups around the world who have undertaken soft path studies. And it was Friends of the Earth in the United States that created the International Project for Soft Energy Paths to hold conferences and put out a professional journal on the subject.

Canada is no exception. Although the earliest soft path studies for Canada were done under the auspices of the Science Council of Canada or of the Department of Energy, Mines and Resources, the individuals involved (Lovins, Robinson and Brooks) were all associated in one way or another with Friends of the Earth or with its member organizations. Moreover, once it became evident that, for a soft energy path study to be truly representative of the opportunities across Canada, it would have to be done on a province-by-province basis, Friends of the Earth got involved directly.

The first direct foray of Friends of the Earth (then only four months old as an organization in Canada) into soft energy path analysis came on Thanksgiving weekend of 1978 when a workshop was convened at Trent University in Peterborough, Ontario. Financed by travel contracts granted by the federal Office of Energy Conservation (the earlier incarnation of today's Energy Conservation and Oil Substitution Branch), some 25 analysts, at least one from each province, came together to discuss the nature of a provincially based soft path study for Canada. Methods were developed, assumptions and standards set, and guidelines proposed for a set of studies that, it was optimistically hoped, would lead to a consistent set of studies. It was not to be. In the absence of a continuing structure and central funding, each provincial team had to find its own funds, create its own base line and make its own projections. While the results, published in issues of the journal Alternatives between Fall 1979 and Fall 1980, were credible enough on a province-by-province basis, there were too many differences to permit addition into any kind of national total.

The study presented here was designed from the start to build on the experience and to learn from the mistakes of the first round of studies. Thanks to a seed grant from Environment Canada, a proposal was developed for a study that would provide funds to support work in each province (and in the two territories, which were not represented in the earlier study), and would include enough money for national and regional meetings of the analysts and for a Secretariat that would run the study and develop an economic and demographic base line and projections that would ensure consistency among provinces. This proposal was submitted to the Department of Supply and Services in May 1980 and was approved in November 1980, with the majority of the funds coming from the Department of Energy, Mines and Resources, Environment Canada, and the Department of Supply and Services. Fortunately, about half the people who had undertaken the first round of studies were also available for the second, and this created a strong core of experience on which newly enlisted analysts could rely.

The study took about 26 months to complete and included three national meetings plus another meeting in each of three regions (West, Ontario & Quebec, Atlantic). In addition, there were numerous smaller meetings and many protracted long-distance telephone calls. We would be less than frank if we did not admit that, in trying to force ten provinces and two territories, each with its own energy mix, into a common method of analysis and a common format for reporting, lots of difficulties arose and many compromises were necessary. Despite all of this, the cameraderie and collegial feeling generated among the analysts on both the first and second studies have been among the most remarkable aspects of the study -- and certainly contributed in no small way to the success of our efforts.

One final word: We want to make the results of this study available to people who have neither the time nor the background required to read the rather detailed presentation of this report. Therefore, we will be publishing a more popular version, in the form of a paperback book entitled Life After Oil, in the fall of 1983. More popular versions of each of the provincial reports may also be developed. In addition, the Executive Summary will be reprinted and distributed as an inexpensive separate item. Finally, if funding sources can be found, we would also like to develop versions of the report using film, videotape and slides, as well as print. We hope to reach not just the already interested individual seeking more information but also those who as yet are unaware of, and thus uninterested in, the soft energy path alternative.

ACKNOWLEDGEMENTS

While many people have helped at one stage or another in the preparation of this study, there are a few whose help has been so significant that we would like to mention them by name. In a special class is Graham Armstrong of the Energy Conservation and Oil Substitution Branch (ECOSB) in the Department of Energy, Mines & Resources (EMR); as scientific authority and Chairman of the Steering Committee, Graham has taken a continuing interest in the project and been enormously supportive throughout.

Close behind Graham in support have been Gary Breen, also of ECOSB, who helped guide us through the labyrinth of the Department of Supply and Services; Kirk Hamilton of the Structural Analysis Division of Statistics Canada, who worked with us on use of the economic model on which our energy projections are based and who answered patiently some hundreds of questions; and Dr. J.A.G. Maini, Director General of the Policy Directorate for Environment Canada, whose early support gave us the courage (and the finances) to propose the new soft path study for Canada. Many others at ECOSB, including notably Charles Ficner, Barry James, Peter Reilly-Roe and Gil Winstanley, provided us with useful information and critiques, as did Roger Peters and Ralph Overend of the National Research Council. Ian Cavanaugh and Donald Wilson of Statistics Canada and Al Coombs of EMR guided us through the complexities of energy statistics. Paul Ray of EMR sat in on some of our meetings and, having had some experience with soft path studies, offered helpful advice.

We would like to thank all the members of our Steering Committee including: Mr. John Hollins, Director, Energy Branch, Corporate Planning Group, Environment Canada; Mr. Joseph McIntyre, Policy Advisor, Policy Directorate, Environment Canada; Mr. Steven Bolcso, Policy Analyst, Ministry of State for Science and Technology; Mr. Peter Van Die, Head, Energy Section, Research Branch, Agriculture Canada; Mr. Kirk Hamilton, Structural Analysis Division, Statistics Canada; Mr. Paul Ray, Director, CHIP Evaluation, Department of Energy, Mines and Resources; Dr. Gil Winstanley, Energy Conservation and Oil Substitution Branch, Department of Energy, Mines and Resources; Ms. Paula Green, Science Procurement Officer, Department of Supply and Services.

We must also express our sincere gratitude to the Department of Energy, Mines & Resources, to Environment Canada, and to the Department of Supply and Services, which collectively provided the funds that made this project possible.

Thanks also to the succession of typists, editors and programmers, especially Mary Ellen Patton, Jean Webster and Dave

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CHAPTER 1: INTRODUCTION

This study, undertaken on behalf of Friends of the Earth in Canada, analyses the feasibility and implications of a particular energy future for Canada, a future based primarily upon efficiency in energy use and renewable energy supplies rather than upon increased growth in energy demand and continued reliance upon non-renewable supplies. It is not a predictive study: no attempt is made to discover or describe the most likely energy future for Canada. At a time when energy and economic conditions are changing radically, such predictions are of limited usefulness, particularly when, as in this study, the time horizon extends to the year 2025. Instead, our study takes a different approach, asking the questions: How technically feasible is a renewable energy future? How economically viable? What would it look like? What would need to be done were we to try for such a future?

In particular, we attempted to answer these questions in the context of the assumption that no radical changes in lifestyles or values took place, that people continued to do much the same kinds of things for much the same kinds of reasons. In other words, ours is primarily what is called an "economic fix" analysis.

1.1 SOFT ENERGY PATH STUDIES

Since 1976, studies that attempt to assess the demand and supply implications of renewable energy futures have come to be called "soft energy path" (SEP) studies, after a term first used by Amory Lovins (1976a, 1977).

Soft energy paths are energy policy paths or strategies directed towards achieving principal reliance upon "soft energy technologies". In turn, soft energy technologies are defined by the following five characteristics:

1. They rely on renewable energy flows that are always there whether we use them or not, such as sun and wind and vegetation: on energy income, not on depletable energy capital.
2. They are diverse, so that as a national treasury runs on many small tax contributions, so national energy supply is an aggregate of very many individually modest contributions, each designed for maximum effectiveness in particular circumstances.

3. They are flexible and relatively low technology -- which does not mean unsophisticated, but rather, easy to understand and use without esoteric skills, accessible rather than arcane.

4. They are matched in scale and in geographic distribution to end-use needs, taking advantage of the free distribution of most natural energy flows.

5. They are matched in energy quality to end-use needs:" (Lovins, 1977, pp. 38-9.)

Soft energy paths exist in contrast to "hard energy paths", i.e. policy paths characterized by an emphasis upon increasing energy supply and by increasing scale, electrification, and centralization of energy production. Clearly, hard paths are more typical of traditional views of likely energy futures; SEP studies have tended to represent challenges to the status quo.

Though diverse in form and content, soft energy path studies have tended to exhibit a number of common characteristics which set them apart from more traditional studies of energy futures. Each of these features will be briefly discussed.

Demand Orientation

In the first place, and perhaps most important, SEP studies embody a different conception of "the energy problem" from that found in most traditional analyses. A conventional conception of the energy problem focusses on the question of ensuring that adequate supplies exist to meet present and future energy demands (Energy, Mines and Resources, Canada 1976, p. 2). This perspective (with its roots in the doctrines of consumer sovereignty and the insatiability of human needs) leads to a supply orientation of policy in which energy demand is treated as virtually exogenous to the policy process, a "given" which must be satisfied by the production of energy supplies. Policy is oriented around predicting "most likely" levels of future supply and demand and providing appropriate incentives, if required, such that "necessary" supplies will be forthcoming in the future.

In recent years, the high economic, environmental and social costs of supply-oriented policies have become increasingly recognized. This has led to a greater awareness of the desirability or necessity of energy conservation. Often, however, conservation is perceived merely as an inherently unpleasant necessity, a short-term method of reducing inefficiency and eliminating waste, the purpose of which is to buy the time necessary to bring new supplies on stream (eg. Gander and Belaire, 1978, p.67). In contrast to this perspective, which leaves the basic supply oriented perspective of policy untouched, is the demand orientation characteristic of SEP studies. A demand orientation is based on the recognition that energy use is only a means to an end, not an end in itself, and that the purpose of energy use is to supply particular services, such as heat, motive power, and so on. A demand oriented definition of the energy problem focusses on the question of meeting end-use needs in the most efficient manner possible, and thus upon the services that energy provides, (Robinson, 1982a). Such an approach asks the question: How can each end-use be most efficiently supplied? As Lovins remarks:

> "in the soft path how much energy we use to accomplish our social goals is considered a measure, not of our success, but of our failure". (Lovins, 1979, 6).

The result of a demand orientation of policy is a primary emphasis upon the consumption rather than the production side of the equation. SEP analyses always start with energy end-uses, which leads to a "bottom-up" form of analysis. In contrast to traditional "top down" approaches, in which energy demand is analyzed as a function of aggregate macro-economic or demographic variables, in a bottom-up analysis energy demand is analyzed as a function of the disaggregated tasks that energy performs (Robinson, 1982a). From this point of view energy conservation is seen not as an inherently undesirable necessity, nor even only as a method of eliminating waste, but instead as the primary component of rational energy planning, the logical first place to focus attention.

Energy Quality

A second defining characteristic of SEP analysis, which emerges directly out of the first, is a concern with the quality of energy used to meet end-use needs. Traditionally, energy analysts have focussed upon the quantity of energy needed to meet expected demands. Indeed, such an approach is reflected in our energy accounting system, which measures all energy sources in common quantitative units such as joules or kilowatt-hours. From the point of view of the user of energy, however, a certain quantity of energy may be of differing value depending upon its quality, which in turn depends upon the form in which it exists. The quality of an energy form is a measure of the amount of "useful work" that can be extracted from the total energy, or enthalpy, contained in that form. For example, one joule of electricity can be used for many more things than a joule of low temperature heat, although the quantity of energy is the same in both cases. The joule of electricity is a higher quality form of energy because it can provide more useful work than the joule of low temperature heat.

An emphasis upon energy quality considerations emerges from a concern with the thermodynamics of energy utilization. In particular it is compatible with an emerging emphasis in the energy literature upon so-called "second law efficiencies" of energy use, which are based on the second law of thermodynamics (American Physical Society, 1975). In contrast to the more familiar "first law efficiencies" which measure the ratio between the quantity of the energy input and of the useful work output of a device such as a furnace, second law efficiencies focus upon the theoretical minimum amount of energy required to perform a particular task. In assessing the efficiency with which these tasks are performed, a second law approach highlights the degree to which energy quality is efficiently used, that is the efficiency with which the available energy or useful work is utilized (Schipper, 1976; Brooks, 1981, Appendix A).

A concern with the quality of energy use is compatible with SEP studies in three respects. In the first place, a second law approach to energy demand analysis reveals a much larger technical potential for energy conservation than traditional analyses. Secondly, this approach, by emphasizing the importance of "matching" energy sources to end-use needs in terms of the quality of energy required, reveals considerable scope for the efficient utilization of renewable energy resources. Finally, a concern with energy quality, and with the tasks performed by energy, inherently requires a bottom-up or end-use approach to analysis, thus further supporting the demand orientation of SEP studies.

Energy Backcasting

A final defining characteristic of SEP studies is the use of alternatives to traditional supply and demand forecasting techniques. Based as they necessarily are upon the analysis of past trends, forecasts are inherently conservative with respect to the types of changes and sources considered in the analysis. They do not lend themselves easily to the analysis of new trends and developments. Just as important, the purpose of forecasts is to provide some estimate of likely energy supply and/or demand futures. Good forecasts would presumably converge upon that pattern of supply and demand most likely to occur, given certain specified assumptions and conditions. It is not clear, however, either that the likely future can be adequately predicted except in times of great stability or, even if it could, that the most likely future is also the most desirable one. It may well be that the most desirable energy future is not particularly likely at present. In such a case, what we would want to know is how to make it more likely, not which other future is most likely.

For both of these reasons, SEP studies have tended to use an alternative method of energy analysis, called energy backcasting. Backcasting analyses are concerned, not with what energy futures are likely to happen, but with how desirable futures can be obtained. They are thus explicitly normative, involving "working backwards" from a particular chosen future end-point to the present in order to determine what policy measures would be required to reach that future (Robinson, 1982b). As might be expected, the end-point used as a basis for SEP analyses is usually a low demand energy future that relies entirely, or almost entirely, on renewable energy flows. In general only the energy characteristics of a society are backcast. That is, given a forecast of demographic and economic variables, goals are set for the energy supply and demand patterns to be associated with the future society described by those variables, and the feasibility or viability of those supply and demand patterns is then analyzed.

The distinction between forecasts and backcasts has important implications with respect to the relationship between analysis and policy. In the first place, energy backcasting is more closely oriented to the policy process than is forecasting. The outcome of a good forecast is an indication of the likely results of certain specified conditions. The outcome of a good backcast is an indication of what policy measures would have to be taken in order to reach a specified goal. Backcasting greatly reduces the tendency, inherent in forecasting, for the results of the analysis to be rendered instantly obsolete by the response to the analysis. It also permits a much better feel for the effects of different policies in the context of the attainment of different policy goals.

Secondly, because backcasting is explicitly normative it is not possible to use the results of backcasting analyses as ostensibly neutral justifications for policy decisions. Not only does the specification of end-points in backcasts require a normative choice to be made for the purposes of the analysis, but the choice of a particular energy future by policy-makers must be justified independently of the backcast itself. This renders impossible a common reversal of cause and effect whereby the future (as revealed in forecasts) is treated as the cause of present events (i.e. policy decisions). Such a reversal obscures the real relationship between policy-making and future supply and demand, and allows the decision-making process to operate under a spurious cloak of objectivity (Robinson, 1982c, 1983).

The difference between forecasting and backcasting is thus as much one of approach as of methods. Both techniques must incorporate policy changes; both must also make use of some predictions; both can be highly quantitative. The value of backcasting, which, in contrast to forecasting, increases as the time horizon of the study is extended, is that it makes possible the exploration of the feasibility and viability of a wide range of possible energy futures rather than, as Rene Dubos stated, elevating trend to destiny.

In varying degrees, these three methodological characteristics -- a demand orientation, a concern with the thermodynamics of energy use, and the use of backcasting methods -- are characteristic of the increasing number of SEP analyses that have emerged since 1976. A partial list of these studies can be found on Tables 1.1A (for Canada) and 1.1B (for other countries). It can be seen from Table 1B that soft energy path studies have been undertaken for a large number of countries with a wide range of economic, social, geographic, climatological and resource characteristics.

TABLE 1.1

CANADIAN AND INTERNATIONAL SOFT ENERGY PATH STUDIES

A. CANADIAN STUDIES
(listed chronologically)

1. Lovins, A., 1976. Exploring Energy-Efficient Futures for Canada. Conserver Society Notes, 1:4.

2. Brooks, D., with Erdmann, R., and Winstanley, G., 1977. Some Scenarios of Energy Demand in Canada in the Year 2025. Report of the Demand and Conservation Task Force, Long-Term Energy Assessment Program, Energy, Mines and Resources Canada, Ottawa.

3. Robinson J., Figuieredo C., Hare G., House-Holder J., Kerwin T., Noble R., Syed N., and Vavasour M., 1977. Canadian Energy Futures : An Investigation of Alternative Energy Scenarios, 1974-2025. Workgroup on Canadian Energy Policy, Faculty of Environmental Studies, York University, Toronto.

4. Crow, R., Szegedy-Maszak, P., and Conway, C., 1978. Energy Planning in a Conserver Society : the Future's Not What it Used to Be. Energy Probe, Toronto.

5. Conway, C., Crow, R., Marshall, B., and Brooks, D., 1979. Energy Planning in a Conserver Society : Implementation Strategies. Energy Probe, Toronto.

See also the ten provincial SEP studies sponsored by Friends of the Earth-Canada and summarized in the following four issues of Alternatives: 8:3/4, Summer/Fall, 1979; 9:1, Winter, 1980; 9:2, Spring, 1980; 9:3, Summer/Fall, 1980.

B. INTERNATIONAL STUDIES
(listed chronologically)

1. Sorensenn, B., 1975. Energy and Resources. *Science*, 189.

2. Lovins, A., 1976. Energy Strategy: The Road Not Taken? *Foreign Affairs*, October.

3. Lovins, A., 1977. *Soft Energy Paths: Toward a Durable Peace*. Friends of the Earth/Ballinger, Cambridge, Mass.

4. Johanssan, T. and Steen, P., 1977. *Solar Sweden*, Secretariat for Future Studies, Stockholm.

5. Dieren, W., Huebing, R., Bydorf, R., and Potma, T., 1977. *Energiebeleid Met Minder Risico (Energy with Less Risk)*, Centrum voor Energiebesparing, Rotterdam.

6. Lovins, A.B., 1977. Soft Energy Technologies. *Annual Review of Energy*, 2: 477-517.

7. Lovins, A., 1978. *Re-examining the Nature of the EEC Energy Problem*. Draft report to the United Nations ECE, Brussells.

8. Les Amis de la Terre, Commission energie, 1978. *Tout Solaire*. J. J. Pauvert, Paris.

9. Craig, P., Christensen, M., Levine, M., Muhamed, D., Simmons, M. (eds.), 1978. *Distributed Energy systems in California's Future*. Report prepared for the United States Department of Energy. Government Printing Office, Washington, D.C..

10. Leach, G., Lewis, C., van Buren, A., Romig, F., and Foley, G. 1979. *A Low Energy Strategy for the United Kingdom*. The International Institute for Environment and Development and Science Reviews, Inc., London.

11. Norgaard, J., 1979. *Households and Energy*. Report No. 4 from DEMO - Project. Physics Laboratory III, Danish Institute of Technology, Lyngby, Denmark.

12. Matteoli, L., Caccia, P., Funaro, G., Grosso, M., Ketoff, A., Pagani, R., 1979. *Sardinia 2010* (in Italian). SOFTEC, Sistemi e Tecnologie a Basso Contenuto di Energia, Torino, Italy. (English summary prepared for International Project for Soft Energy Paths, San Francisco.)

13. Sant, R., 1979. *The Least-Cost Energy Strategy*. The Energy Productivity Center, Carnegie Mellon Institute, Arlington, Virginia.

14. Kalinsky, A., 1979. *Solar Energy: The Main Soft Energy in Israel*. Paper prepared for the International Project on Soft Energy Paths, San Francisco.

15. Tsuchiya, H., 1980. *A Soft Path Plan for Japan*. Research Institute for Systems Technology, Tokyo, Japan.

16. Sorensen, B., 1980. *Renewable Energy Planning*. The Neils Bohr Institute, University of Copenhagen, Denmark.

17. Lovins, A., 1980. Economically Efficient Energy Futures. In Bach, W. *et al* (eds.), *Interactions of Energy and Climate*. D. Reidel, Dordrecht, Netherlands.

18. Atterkvist, S. and Johansson, T., 1980. *Solar Norway*, English summary of *Sol-Norge* (Universitets forlaget, Oslo), Paper presented at the Second International Conference on Soft Energy Paths, Rome.

19. Reddy, A., 1980. Alternative Energy Policies for Developing Countries: A Case Study of India. Proceedings of the IESI Symposium at the University of Tennessee, October 1980. In Bohm, R.A. *et*. *al*. (editors), *World Energy Production and Productivity*. Ballinger, Cambridge, Mass.

20. Singh, G., 1981. *Malaysia's Soft Energy Path*. Paper presented at the Second International Conference on Soft Energy Paths, Rome.

21. Solar Energy Research Institute, 1981. *A New Prosperity : Building a sustainable Energy Future*. Brick House Publishing Co., Andover, Mass.

22. Sorensen, B., et al, 1981. *Nordisk Energisamarbete*. Phase 1 of a project on the Nordic Energy System.

23. Messenger, M. 1981. A High Technology - Low Energy Demand for Western Europe. *Energy: The International Journal*, 6: 1481-1503.

24. Sorensen, 1981. Renewable Energy Planning for Denmark and Other Countries. *Energy: The International Journal*, 6: 293-303.

25. Lovins, A.B. and L.H. Krause, K., and Bach, W., 1981. *Least-Cost Energy: Solving the CO2 Problem*. Brick House Publishing Co., Andover, Mass.

26. Oliver, D., Miall, H., Nectoux, F., and Opperman, M., 1982. *Energy-Efficient Futures: Opening the Solar Option*. Earth Resources Research, London.

27. Sorensen, B., 1982. An American Energy Future. *Energy: The International Journal*, 7: 783-99.

28. Goldemburg, J., 1982. Energy Issues and Policies in Brazil. *Annual Review of Energy*, 7.

29. Johansson, T., Steen, P., Bogren, E., and Fredricksson, R., 1982. *Sweden Beyond Oil II: The Efficient Use of Energy*. Environmental Studies Program, University of Lund, Lund, and National Defense Research Institute, Stockholm.

30. Manton, B.E., *et. al.*, 1982. *Towards a Sustainable Energy Future for Victoria: An Energy Efficiency Scenario*. Australian Conservation Foundation, Hawthorn, Victoria.

1.2 SOFT ENERGY PATHS IN CANADA

In general, the SEP studies shown on Tables 1.1A and 1.1B have focussed upon the technical, and to some extent economic, potential for soft energy paths in their respective countries. In each case the potential appears large, limited much more by policy will than by resource constraints. This conclusion holds true for the Canadian SEP studies shown on Table 1A which all suggest that a renewable-based energy future for Canada is technically feasible.

As yet, however, these analyses have been incomplete in three main respects. In the first place, previous Canadian studies have been severely limited in terms of the amount of money and time that was put into them.

Secondly, these studies have oscillated between aggregate national analyses, which necessarily excluded regional differences, and separate provincial studies, which captured these differences but were not themselves compatible with other provincial studies. In Canada perhaps more than most countries it is desirable to have a study done which is both national in scope and regional in detail and analysis. Finally, in previous Canadian studies, too little attention has been paid to the economic viability of the soft path scenarios developed and little or none to social and environmental implications.

These three factors conditioned the design of this Canadian SEP study which was developed by Brooks, Robinson and several of the original provincial researchers on the basis of their experience in earlier Canadian SEP studies. In the first place, it was designed as a national study, with a consistent set of national parameters for population and economic growth, appliance efficiencies, transportation technology, etc. This ensured that the study was consistent across the country and provided a framework for the analysis.

The study itself, however, was broken up into twelve parts, one for each province and the two territories. A Provincial Research Team was set up for each "province" and each study was carried out independently by each team in the context of the national parameters and frequent consultation with the national Secretariat. This ensured that regional variations in supply and demand options were maintained.

In this study primary emphasis was placed upon the economic viability rather than the social and environmental implications of the analysis. As discussed in detail in the next chapter, two scenarios were developed, both based on Statistic Canada's Long Term Simulation Model (LTSM), a materials balance model of the Canadian economy based upon input-output tables. The first scenario was used in a pure economic fix analysis -- no supply or demand measure was invoked that was not cost-effective against conventional fuels. Somewhat more latitude was given for the second scenario but in no case were extremely uneconomic measures introduced. The result was a set of analyses that were deliberately biased in a conservative direction. Although the time horizon of the study was 47 years, no technological breakthroughs were included. Despite the immature state of most renewable energy technologies, few reductions in cost for unconventional technologies were allowed. Moreover, in both scenarios people continue to do much the same kinds of things as they do today. In other words our "business as usual" scenario is in many ways a "worst case" scenario, illustrating the potential of soft energy paths under very conservative conditions (see Appendix 2.2).

The use of the LTSM materials balance approach and the division of the study into individual provincial analyses, plus the demand orientation inherent in SEP analyses, mean that this study was a "bottom up" analysis in three senses: respectively, economically, geographically and energetically. These methodological characteristics helped to ensure that the study was anchored to provincial conditions and to physically consistent materials flows despite the long time horizon of the study.

However, for both practical and methodological reasons, there were limitations on the degree to which this study could conform to the three methodological characteristics of SEP studies noted above. First, and most important, this study is not a full but only a partial backcast. In particular, no attempt was made to detail in advance the energy supply or demand levels or the energy mix for the end-point year, 2025. Instead a general goal was set: to test the technical feasibility and economic viability of a wide range of energy conservation and renewable energy options, given certain assumptions about energy pricing and given the economic scenarios defined by the LTSM. In keeping with this goal, certain energy supply options, such as Arctic oil and new nuclear power stations, were excluded from the analysis, and other options, such as large-scale coal and hydro projects, were de-emphasized. In other words the study represents a backcast of a future society in which these options would not be available and in which conservation and decentralized renewable energy would be developed to their economic potential. As with all backcasts, it serves as a test for the feasibility of soft path options rather than as a prediction of their likelihood.

In addition, although the analysis is clearly demand-oriented in that the focus of analytical attention is on energy end-uses, defined in terms of energy quality categories, there were limits on the degree to which we were able to analyze energy end-uses and second law efficiencies. The energy end-use data base in Canada, as in other countries, is quite poor and we were forced to develop our own categories and attempt to fit what little end-use information currently exists to those categories. Moreover, as discussed in Chapter 2, the method we used to analyze conservation potential in the Industrial and Transportation sectors seriously constrained our ability to incorporate the full potential for conservation in the analysis.

For all of these reasons, our study represents a compromise between what was methodologically desirable and what was possible to do. It is hoped that future work can extend and improve upon this analysis.

1.3 RESULTS OF THE STUDY

The results of this study can be summarized most briefly as follows: under conditions of strong economic growth (an increase of more than 200% in Gross Domestic Product -- GDP) and moderate population growth (an increase of over 50%), it would be technically feasible and cost-effective to operate the Canadian economy in 2025 with 12% less energy than it requires today, and, over the same 47 year period, to shift from 16% reliance on renewable sources to 77%. In addition, should the economy grow by "only" 140% to 2025 (with the same population growth), and should the real of soft technologies drop slightly, it would be feasible and cost cost-effective to use 34% less energy in 2025 than in 1978, with 82% of that energy provided by renewable sources. (Technical feasibility is defined in terms of the availability today of either off-the-shelf or prototype technology. Cost-effectiveness is defined in terms of the long-run marginal costs of alternative ways of supplying energy in Canada.) Over the study period energy use per capita falls to between one-half and two-fifths of its level in 1978, and energy use per dollar of GDP to just over one-quarter of its 1978 level.

The results reported in this study may seem surprising to those familiar with more traditional studies of possible Canadian energy futures. Given the unconventional method and approach of SEP studies outlined above, it could be expected that the results of such studies have in the past tended to be at considerable odds with conventional wisdom on energy issues. Lovins' early work, in particular, was subject to great criticism by industry and government spokesmen and academics (Nash, 1979). In recent years, however, the conclusions reached in the increasing number of SEP studied produced globally (see Table 1B) have begun to seem less unconventional and more prophetic. In particular, official demand forecasts have been dropping radically in the U.S. (Marshall, 1980) and Canada (Brooks, 1981; Robinson, 1982a). In addition a recognition of the policy-determined nature of available supply and demand futures has led to the realization that what energy future we will have is largely a question of choice. The National Energy Program states it well:

> "While most conventional forecasts imply a relatively modest role for renewables, it is clear that many Canadians do not share that view. Indeed, the dramatic surge in the use of wood for home heating and as a fuel in the forest industry suggests that these forecasts understate substantially the contribution to be made. Moreover, while forecasts are useful tools for analysis, they can tell us only what will happen under certain conditions. The conditions - the policies - are the keys. Many thoughtful and concerned Canadians believe that we should alter the forecast, that we should decide soon on a preferred energy future, and establish the conditions that will take us there" (Government of Canada, 1980, p. 65).

1.4 ORGANIZATION OF THE STUDY

The study is contained in twelve volumes. The first volume comprises a national overview of the methods, results and implications of the analysis and is organized as follows. Chapter 1 is the introduction. Chapter 2 contains a detailed discussion of the method used in the study, including a list of the assumptions and parameters within which the provincial analyses were undertaken. In Chapter 3 the quantitative results of the study are outlined at the national level. A discussion of policy implications, implementation issues and impacts follows in Chapter 4. Chapter 5 contains suggestions for further research, and Chapter 6 contains our conclusions.

Volumes II through XII present the results of the provincial studies. Following a brief introductory chapter, each provincial volume is divided into seven parts. The first two parts describe the current energy situation in the province and outline the future economy of the province as projected in the analysis. Then the results of the analysis are presented in three parts, covering respectively energy uses, energy sources, and energy supply/demand balances in 2000 and in 2025. (Exactly the same sequence is followed in the Results chapter of Volume I.) Finally, a sixth section contains a discussion of impacts and implementation.

In each of the provincial volumes a standard set of numbered tables and figures is provided. This makes for easy comparison of assumptions and results among different provinces. Additional tables and figures may be included in any chapter but these are unnumbered. The same tables and figures for Canada as a whole are contained in Chapter 3 of this volume of the study. These national tables and figures have the same titles and numbers as the standard provincial tables and figures (that is Table or Figure CA-4 for Canada corresponds to Tables or Figures NS-4 for Nova Scotia, SK-4 for Saskatchewan, etc.).

One of the major contributions of this study is the building up of a national picture of soft energy path options on the basis of detailed provincial analyses. While the national results contained in Volume I embody, in an aggregate form, the findings of all of the provincial studies, a complete understanding of regional variations and the details of soft energy potential and implications can only be developed by examination of the provincial studies contained in Volumes II through XII. In each case these studies are a summary version of a much more detailed provincial analysis than could be displayed in this report. Further details on these provincial analyses can be obtained from the authors of each individual provincial study.

CHAPTER 2: METHOD AND BASIC ASSUMPTIONS

The general approach to soft path studies described in Chapter 1 has led to the development of a common method of analysis, as described in Brooks and Casey (1979). However, there are innumerable issues that need to be resolved for any individual study, and many more when the study begins with 12 separate pieces as does ours for Canada. This chapter will describe in detail the methods and assumptions that were necessary to build the energy economy of each province from the bottom up and to build that of Canada from the 10 provinces and 2 territories. However, the first section of the chapter contains an overview of the method. Readers interested mainly in results may find it convenient to read only this section and then go directly to Chapter 3. Following the overview section, discussion will cover first the method for projecting the future economy to be studied, including population growth, economic growth and pricing and costing. The discussion will then proceed to cover the energy economy, including sources of information, energy demand by sector and energy supply by form. Finally, the method of integration within provinces and from 12 regions to Canada will be discussed. Appendix 2.1 is a succinct outline of the method of analysis used within each province and territory, but it does not incorporate the steps necessary for national integration.

To the extent that there is a specific model for the Friends of the Earth Soft Energy Study for Canada, it would be the study completed by Leach and his colleagues for the United Kingdom (1979). Some components of our work, particularly those required to integrate the 12 regional soft path studies into a single national one, owe a debt to a four-country analysis still underway in Scandinavia (Sorenson, 1981).

In any study that attempts to break with the conventional energy studies, and ours makes such a break both in method and in results, it is essential not only to avoid bias but to avoid the appearance of bias. While not exactly prejudicing the case against soft energy paths, we have made efforts to be conservative. When options are available, we have generally chosen that one which would be less or least favourable to the soft path case. This technique, dubbed "multiple conservatisms" in soft path jargon, is of course intended, in the final analysis, to lend even more weight to the final results. A list of the more important conservatisms appears as Appendix 2.2, and they are emphasized whenever relevant in this chapter.

2.1 OVERVIEW OF METHOD

The basic approach adopted to analyze soft path alternatives for Canada in 2000 and 2025 involved the integration of micro-economic information on the cost effectiveness of specific energy conservation and renewable energy techniques with a macro-economic projection of the Canadian economy. While not different in overall approach or in general results from soft path studies undertaken in other countries, this study does incorporate two unique methodological aspects. First, the study is based on an integrated economic model that adjusts industrial output for changing demographic characteristics and consumer expenditure patterns rather than on a simplistic expansion of the economy. Second, the results are based not merely on a bottom-up approach to energy use by function (an aspect that almost defines soft path studies) but also on a bottom-up approach to enery use by geography in the sense that soft energy paths were developed for each province and territory and then added algebraically to create a soft energy path for Canada. No other soft path study of which we are aware is based on so sound an economic base or so disaggregated a geographic base.

In more detail, the study can be viewed in terms of five sequential steps.

(1) The first step involves the development of scenarios of the Canadian economy over time with allowance for a growing population (particularly in western provinces) and a growing industrial base. This step, which could be enormously difficult (hence, the simplistic approach commonly adopted), was made relatively easy because of the availability at Statistics Canada of a long-term simulation model of the Canadian economy. This model is based on input-output tables which are very detailed and capable of projecting industrial output forward in a consistent way. For example, it reacts to a growing but aging population by shifting public investment from schools to hospitals and simultaneously allows for enough iron ore mining, steel making and highway construction to provide for the automobiles that the larger population is likely to demand. It must be emphasized that this simulation model was used to project the economic characteristics of the society, but not the energy characteristics; the latter were developed independently--indeed, they formed the core of the study--and they were grafted onto the framework provided by the former. While another iteration of the model, incorporating the effects of the energy analysis on the economy, would have been desirable, resources did not permit such a feedback step.

The simulation model also provided the controls necessary for integrating provincial results into national ones. That is, the sum of provincial population levels in any year equals the national population, the sum of steel output in the provinces equals national steel output, the sum of provincial investment equals national investment, and so on.

Two pre-existing runs of the long-term simulation model of the Canadian economy were adopted to provide scenarios for analysis of soft energy paths. Both were available from work done by Statistics Canada for the Privy Council. The two scenarios incorporate the same rate of population growth (approximately 1% per year 1978 to 2025), the same westward shift of the population and essentially the same growth in labour productivity, but they differ in economic growth and were treated differently in the energy analysis. The Business as Usual scenario grows nationally at 2.6% per year to 2025 (4.3% per year 1978 to 2000), and the Consumer Saturation scenario grows at 1.9% per year to 2025 (2.6% per year 1978 to 2000). The difference between the two is not, however, simply a matter of aggregate growth rates but of different ways of tying the economy together. In Business as Usual full employment is maintained by keeping constant labour hours worked per person per year, whereas in Consumer Saturation full employment is maintained by trading income for leisure so that labour hours per person-year fall by about 30%. In terms of the energy analysis, no energy conservation or renewable energy technique was introduced into the Business as Usual scenario until it was cost-effective, nor was any lifestyle change incorporated. In the Consumer Saturation scenario somewhat less than fully cost-effective scenarios were incorporated and modest lifestyle changes allowed at the discretion of provincial analysts. (Throughout the study, national economic controls and national energy targets kept the provincial studies linked together, but rates of implementation of each technique varied from province to province along with variations in populations and economic growth.) Cost-effectiveness was measured against actual and projected real replacement costs for fossil fuels, and against costs for new nuclear-generated and (in Saskatchewan and Alberta) coal-generated electricity.

The difference between the two scenarios creates a framework for analysis of two rather different futures for Canada in 2000 and 2025. However, neither is an extreme case. Business as Usual is less expansive than an all-out growth economy, and Consumer Saturation is much more expansive than a conserver society. Moreover, because of time and data limitations, many attractive options from a soft energy point of view, including more durable products and less motorized transportation, could not be incorporated into the study.

(2) The second step in the soft path analysis involved the determination of how much energy of what kinds is needed to provide efficiently for the residential, commercial, industrial and transportation activities identified in each of the two projection years (2000 and 2025) and for each of the two scenarios. This was accomplished by dividing the required energy services into quality categories (heat at various temperatures, liquids, electricity) and finding cost-effective ways of determining the minimum amount of energy needed to obtain the energy of the appropriate quality for each specific service. In cases where commodities are designed or produced on a national basis, the

cost-effective levels of energy efficiency were set on a national basis, but in all cases new techniques were introduced at rates appropriate to the individual provinces and territories. In cases where national targets were not set, provincial analysts could generally focus on those industries or activities most important to their province (fishing in Newfoundland, pulp and paper in New Brunswick, agriculture in Saskatchewan). The result of this process was a set of energy end-use requirements disaggregated by province/territory, by sector and by quality. As with everything else in this study, these results could be aggregated to create totals by sector and by quality for Canada.

(3) The third step involved the development of an appropriate energy supply mix to match the demands identified in step (2). Conventional energy supplies were, with some exceptions, included in the analysis to the extent that identified resources were sufficient and costs low enough. The exceptions included sources that were not considered acceptable for social or environmental reasons in a soft energy study: no Arctic oil, no coal-based liquids, and no nuclear power from plants not already under construction in 1978 was included. (Also, in some provinces certain rivers and certain sources of biomass were excluded and coal-generated electricity was de-emphasized.) Among other conventional sources, offshore oil from Hibernia, another large tar sands or heavy oil plant, Sable Island natural gas and several hydroelectric projects were included in our scenarios. New renewable sources were evaluated on exactly the same basis as conventional except that, rather than deriving cost figures from government reports, cost projections were developed explicitly for the purposes of this study on the basis of the best available information and such experience as exists. The renewable energy sources were introduced gradually as they became cost-effective, and they were matched to the energy demands so as to provide energy of the appropriate quality. Care was taken to ensure that supplies of, say, biomass resources were adequate to the demands being placed on them (without taking any land now used for food production) and to allow for losses because of technical inefficiencies at each stage of production. In addition, provision was made for energy sources used in non-energy products. In this way a set of energy supplies (that is, primary sources linked to secondary forms linked to specific end-uses) were built up by province/territory and by quality, which in turn could by added to create national totals for each source and form by quality.

(4) The fourth step in the development of the soft path results was the integration itself. This involved more than simple addition because, even after economically feasible ways to conserve energy and to develop local, renewable sources of energy had been reviewed, some provinces remained in an energy deficit position (mainly a lack of ability to produce liquid fuels for transportation) and others were in an energy surplus position. Allowing for energy transportation and transmission

required a long series of adjustments as, for example, the movement of natural gas from Alberta to Manitoba required extra energy for production and pumping in Alberta and for pumping in Saskatchewan. Finally, requirements for energy imports and opportunities for energy exports were determined.

(5) The final step in the soft path analysis involved developing the implications of the analysis. This meant, most importantly, assuring that there is a feasible scheme for implementing the soft path results projected for 2000 and 2025 and identifying the major implications from the changes that would be necessary for Canada to begin to move onto that path. Finally, some impacts of a soft path on, among other things, economic issues such as employment, social issues such as income distribution, and environmental issues such as land use were suggested. However, the final chapters of the report are not intended to select among alternative ways of achieving soft path results in Canada, but merely to show that they can be achieved and to suggest that they would likely be desirable.

2.2 THE ECONOMIC AND DEMOGRAPHIC BASE OF THE STUDY

The LTSM Model

A major weakness of most, if not all, soft energy studies to date has been the lack of any integrating model of the future economy in which alternative energy strategies are operating. The issue here is not that of cost-effectiveness on a micro-economic level, which typically is carefully specified in soft path studies, but the viability and consistency of activities taking place on a macro-economic level throughout the economy. Of course, past studies did incorporate specific assumptions about population growth and income growth, but these are only necessary and not sufficient to describe the number and type of energy-using transactions in an economy. Additional specification in terms of the share of national product originating in, say, the steel industry or residential construction is needed to ensure that the former is producing enough to supply the latter or that the freight transportation sector has grown sufficiently to ensure delivery.

There are a couple of reasons why the macro-economic side of soft energy path studies has been neglected. For one thing, there is an inherent chicken-and-egg problem: the nature of economy being projected forward depends in no small way on the nature of the energy system that is going to be developed (in subsequent analytic stages) to service that economy. For example, the relative growth of single-family units compared with apartments, the share of individual compared with public modes of transportation, and the extent to which consumers opt among durable goods, nondurable goods and services (to say nothing of leisure) are each simultaneously critical to the level and form of energy use as well as to the size and structure of the economy. Clearly, it would be possible to specify economies in which the implementation of soft paths would be easy and others in which it would be difficult, but what is the justification for making either assumption?

There is a further problem. Soft energy studies focus on the long term, not the short. Typically they look ahead to (or, more accurately, look backward from) a point some 50 years in the future. This long view is necessary in order to allow for the amortization of capital currently invested in hard energy sources and to allow for the replacement of energy-inefficient buildings and producer and consumer durables. It does, however, complicate the problems involved in the economic projections used as a basis in such studies.

In searching for an economic modelling approach that would satisfy the needs of soft path analysis, conventional approaches, as defined by the National Energy Board (1981), have had to be rejected. Econometric analysis typically provides little more than a larger version of today's economy, more or less modified by the price and income assumptions. Such models are modest about their ability to project more than 10 years ahead and quite incapable of going beyond 15 or 20. Deterministic models do relate specific levels of economic activity to energy use but beg the point of determining the levels of activity. And of course models based on anticipated plans of the energy industry are simply beside the point.

In these circumstances, the Long Term Simulation Model (LTSM) of the Structural Analysis Division, Statistics Canada (Hoffman et al, 1976) has much to offer. The LTSM is intended to represent the Canadian economic system, viewed as an interface between human needs and the physical universe. Emphasis is placed on the physical flows of material including the ability to obtain resources, the techniques involved in their transformation and the need to dispose of wastes, rather than on price and income elasticities. Since this model is not well known, and since it therefore provides the soft energy study with a somewhat different base from comparable studies, a description of the model will be cited at length:

> "The Long Term Simulation Model...represents an attempt to...provide a method for simulating various economic growth scenarios. The approach taken to accomplish these objectives is in sharp contrast to more traditional economic models which explain the evolution of the economic system as a function of the behaviour of economic agents under the assumptions that whatever is required from the physical system is available. This model, rather, places emphasis on

> modelling the flows of materials within the economic system and the ways in which these materials are transformed into finished products. We wish to ensure that these flows and transformations are feasible from the point of view of availability and the physical laws that govern transformation.
>
> . . . .
>
> "The physical orientation of the LTSM is achieved by basing the model on a highly disaggregated constant dollar Input-Output system. Resource use, labour demand, and capital requirements are all related technologically to sectoral gross production in constant dollars. Sectoral production is determined by industry technology and the complete set of transactions between sectors necessitated by the demand for final goods. Demand formation is largely driven by population, the major exogenous variables being per capita (constant dollar) consumer expenditures, investment levels, and total exports. The underlying population model starts with a recent population distribution and traces its evolution fairly mechanically using age-sex specific birth and death rates as well as the external effects of emigration and immigration; the major exogenous population variables are aggregate fertility and the rate of immigration." (Gribble and Hamilton, 1977.)

From the point of view of soft path studies, the advantages of the LTSM include its focus on the long term, its emphasis on technological feasibility and its internal consistency. It allows for a variety of scenarios and for fairly easy changes in basic demographic and economic characteristics. As a materials balance model, there is no need to estimate in advance price and income elasticities for each form of energy in each sector of the economy. The elasticities come from the interplay of technical and economic factors in the analysis; they are derived from rather than used to produce the results. Finally, as much as any projection can, the LTSM avoids predetermining the nature of the final economy in ways advantageous or disadvantageous to the study. Indeed, the LTSM projects only the "industrial" sectors of the economy -- primary industries, manufacturing, and business and commercial services. Projection of the households sector -- housing plus personal automobiles -- and the government sector must be accomplished outside but in connection with the model.

There are disadvantages to the use of the LTSM. Some problems inhere in the model itself. First, the LTSM suffers from all of the defects implicit in the input-output models on which it is based, including the assumption of fixed production technology (based on 1974) and constant dollar relationships among commodities. To some people, the lack of direct price influence is also a problem. However, our method avoids the problem, inherent in price-based econometric projections, of basing the projections on precisely those variables (price and income elasticities) that one wishes to analyze. Second, the economic sectors projected by LTSM bear little relationship to the sectors for which energy data are available. And, third, there is only a national model; provincial submodels are not available. Other problems stem from application of the LTSM to our soft path study. For one thing, use of the LTSM severely limits the degrees of freedom available to balance energy supply and demand. For example, because each of the major transportation subsectors (except private automobiles) is projected by the model, there is no opportunity to shift people and goods from one transportation mode to another (as from private automobiles to public transit). Moreover, the LTSM projects conventional energy supply industries as if they were any other sector, yet growth in these sectors is bound to be lower in a soft energy future. Finally, any province which started with a zero for the output of some sector in 1975 ended up with a zero throughout the projection period as a result of the overriding logic of multiplication.

Techniques were available to cope with some of these disadvantages. First, while constant technology has to be accepted in general, it was not accepted so far as energy was concerned. Every effort was made in the study to identify ways to alter the efficiency with which energy is extracted, transported and used. Second, while prices and costs do not alter the general industrial mix within LTSM, they do have a profound influence in our study on the nature and rate of energy use inasmuch as the selection of conservation technologies and the shift from nonrenewable to renewable sources are both based on cost-effectiveness. Third, the national study was broken down into provincial output according to the shares of provincial output in 1975. These shares were not held constant over time but varied with population shifts among the provinces. (Basically, primary industries were assumed to remain in their current locations despite population shifts; secondary industries shifted half as fast as population; and tertiary industries shifted with population.) Fourth, separate calculations were made to introduce new industries, as with an oil industry in Newfoundland, in provinces where no such industry existed in 1975.

Population Growth

Population projections to the year 2025, the terminal point for our study, distributed by province are unavailable from conventional Statistics Canada publications. Despite this, it was essential that we adopt a national projection that would match that built into in some pre-existing runs of the LTSM (see below). Fortunately, a study had been carried out by Statistics Canada that projects provincial population out to the year 2000 and that matches in fertility rates and immigration assumptions the figures built into the LTSM (Statistics Canada, 1980). In this projection Canada achieves the replacement level total fertility rate of 2.1 by 1991 and net international migration to Canada is assumed to average 100 000 persons per year. In addition, assumptions about inter-provincial migration are adopted such that the gradual shift of population to the western provinces would continue. (In recent years between 35 and 40% of all interprovincial migrants have gone to Alberta or British Columbia.) For purposes of this study, the same rates of internal population growth and interprovincial and international migration were continued after the year 2000 in order to project the final results to 2025. The population projections used in this study appear in Table 2.1 and are displayed in Figure 2.1.

In a few cases the provincial projections resulting from the assumptions seemed too high or too low, and some adjustment was therefore necessary. In particular, based on the difference between national and provincial forecasts, some 100 000 people were shifted from New Brunswick to Newfoundland (and the rates of growth of the economies adjusted accordingly). The final population figures used in the study are shown on Table 2.1. Population growth and distribution did not vary by scenario (as did economic growth).

Economic Growth

Given the selection of the LTSM as the appropriate modelling framework, it remained to find economic growth scenarios for Canada that would be reasonable in the sense of projecting a Canada that was neither merely a grossly enlarged version of today's economy nor one so constrained in energy supply or demand that it would be unrecognizable. The time frame for the study was set at 47 years: from 1978 (the last year for which complete energy statistics had been published when our study began) to 2025, with an intermediate point of analysis at the year 2000. This is long enough to obtain significant change in the energy system but also long enough for poorly designed scenarios to yield ludicrous results.

Fortunately, given the limitations of time and money for this study, the Structural Analysis Division of Statistics Canada had used the LTSM to develop several scenarios of Canadian economic growth on behalf of the Privy Council Office (McInnis and Trepanier, 1979). The scenarios had been constructed so as to provide a reasonable range of likely futures for consideration by Federal policy makers.

Two scenarios were adopted to provide a range of results for our soft energy study. The first, entitled Business As

TABLE 2.1

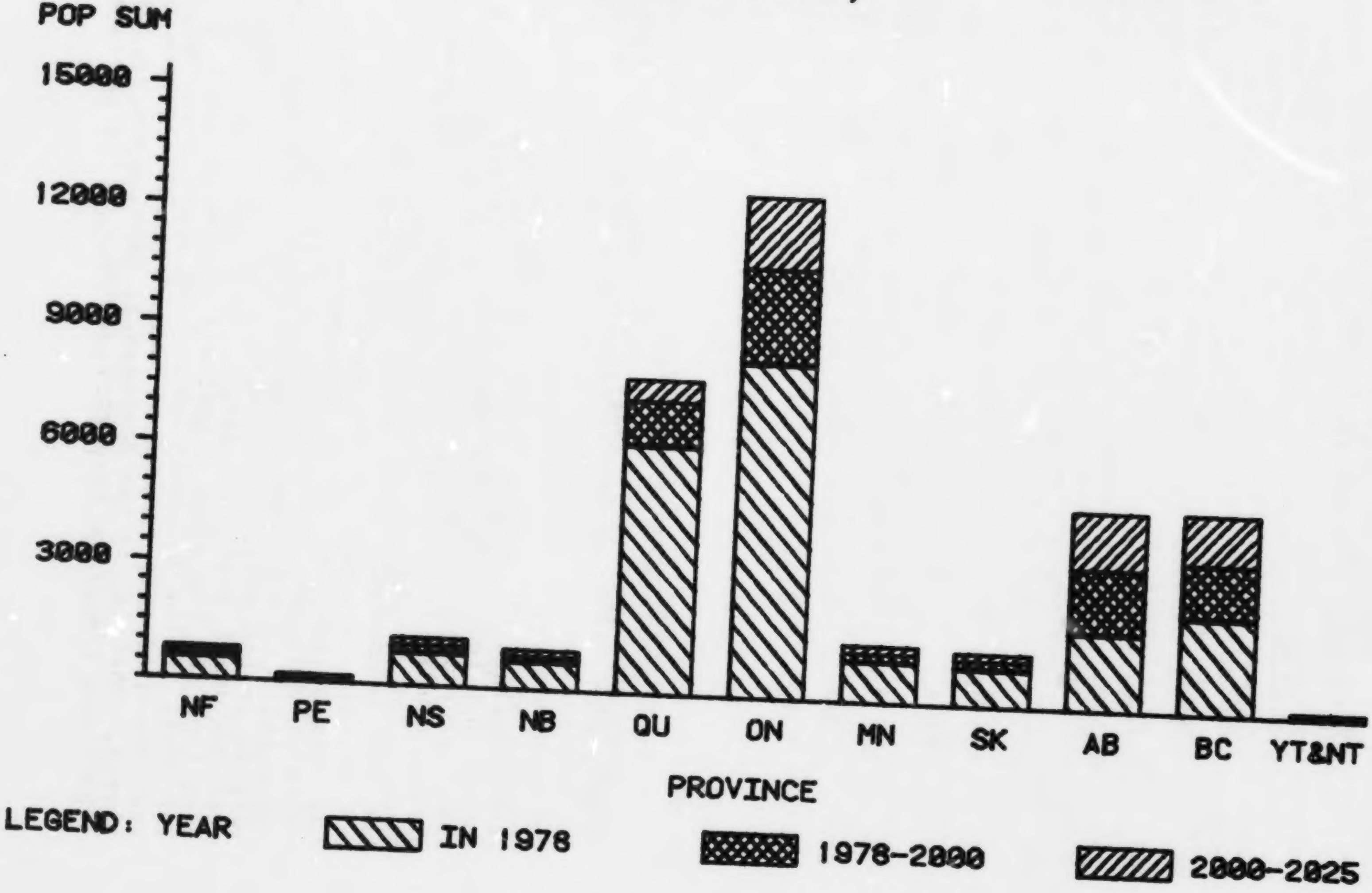
POPULATION PROJECTIONS BY PROVINCE
(ACTUAL 1978 AND PROJECTED 2000 AND 2025)

	1978		2000		2025	
	1000s	%	1000s	%	1000s	%
NF	569	2.4	735	2.4	827	2.2
PE	122	0.5	158	0.5	191	0.5
NS	841	3.6	1034	3.3	1215	3.3
NB	695	3.0	846	2.7	1009	2.7
QU	6273	26.7	7402	23.9	7929	21.5
ON	8444	36.0	10846	35.0	12653	34.3
MN	1034	4.4	1250	4.0	1453	3.9
SK	948	4.0	1164	3.8	1355	3.7
AB	1954	8.3	3591	11.6	5039	13.7
BC	2430	10.4	3803	12.3	5067	13.7
YT/NT	65	0.3	120	0.4	155	0.4
CANADA	23375	100.	30947	100.	36893	100.

Usual, maintains modest rates of output growth, disposable income and technological development; however, over time consumer expenditures tend to shift (as they do in most other growth models) from durable goods to services because of saturation. The second, entitled Consumer Saturation, incorporates the same assumptions about growth potential and about technology but in this case some of the gains from technology are taken in the form of reduced labour time rather than increased expenditures on services (expenditures on durables are very close to identical). Hence, the projected output does not grow so rapidly as in the Business as Usual scenario. In brief, the Business As Usual scenarios keeps labour hours per year constant over time and the added disposable income is spent on goods and services; in the Consumer Saturation scenario labour hours per year are gradually reduced so that disposable income grows more slowly. That is, in the Business as Usual Scenario, people work longer and therefore have more income; in the Consumer Satura-

FIGURE 2.1

POPULATION GROWTH BY PROVINCE
(THOUSANDS)



tion Scenario, they work fewer hours and thus have less income. Note that the model as such cannot tell us which is cause and which effect. As an example of a way in which the differences between the two scenarios could come about, think of two ways of obtaining vegetables for the table. Under Business as Usual conditions, people will be working longer hours and presumably have less time for home gardening among other things, so they will buy more vegetables (whether from a supermarket or their local organic health food co-op); under Consumer Saturation conditions, people will have more non-working time so, in addition to some market purchases, they could grow some of their own vegetables, which takes this much of the service out of the GNP. Table 2.2 details the growth projected for each industry under the two scenarios; Table 2.3 summarizes, and Figure 2.2 illustrates, the rates of growth.

While recent experience suggests that the growth rates, particularly during the first half of the study period, are on the high side, Business As Usual does not represent an all-out growth scenario nor does Consumer Saturation represent a conserver society. Rather, the two bracket a range of moderate growth possibilities under assumptions that seem reasonable about the nature of industrial production and the use of consumer incomes. However, as will be discussed in Chapter 6, differences in growth rates do have a substantial effect on energy use, and therefore the selection of relatively strong economic growth in this study has important implications for the results.

For the purposes of this study, other differences were introduced in the two scenarios so that, besides differing in rate and pattern of economic growth, they also differ in energy characteristics. So far as demand goes, the Business As Usual scenario is kept as close as possible to an economic fix approach; that is, most technologies incorporated are currently cost-effective (at a 7% real discount rate), and all others are projected to be cost-effective by the time they are introduced. In addition, no lifestyle change is permitted apart from trends clearly evident in 1978 (as to smaller families). For the Consumer Saturation scenario strict cost-effectiveness criteria were violated for some options and lifestyle changes were introduced so long as the society was still feasible and recognizable for the province in question. Given the difficulties of determining "costs" for many conservation actions (eg. smaller automobiles) and of finding a line between economic criteria and lifestyle criteria (smaller cars may be more efficient but less prestigious to some), no national guidelines were set for such changes. The same sorts of problems also arose on the supply side and they proved even more intractable. Cost-effectiveness was hard to estimate for technologies such as solar water heating that are still immature and under active development. In the end, it proved to be impossible to apply the criteria for distinguishing between the two scenarios with complete consistency. For the most part, energy sources were matched to end

TABLE 2.2:

ECONOMIC PROJECTIONS FOR CANADA (LTSM SCENARIOS BY INDUSTRIAL SUB SECTOR)

(Millions of 1980 dollars)

		2000		2025		Avg. Annual Growth 1978 - 2025 (%/a)	
	1978	Business as Usual	Consumer Saturation	Business as Usual	Consumer Saturation	Business as Usual	Consumer Saturation
Agriculture	19,678	30,073	26,250	35,670	32,174	1.3	1.1
Forestry	5,096	9,736	7,235	12,301	8,500	1.9	1.1
Fishing, Hunting & Trapping	966	1,459	1,222	1,628	1,499	1.1	0.9
Iron Mines	1,376	3,266	2,239	4,378	2,608	2.5	1.4
Mineral Fuels	13,277	21,498	16,543	25,498	19,250	1.4	0.8
Other Mining	11,898	26,826	18,388	35,567	22,459	2.4	1.4
Food Processing	28,866	45,667	41,137	56,394	51,717	1.4	1.2
Pulp and Paper	23,341	55,495	37,901	74,173	45,021	2.5	1.4
Iron & Steel	16,098	35,452	25,082	45,344	34,437	2.2	1.6
Smelting & Refining	12,942	30,988	21,145	41,688	25,180	2.5	1.4
Cement	718	1,390	1,040	1,703	1,338	1.9	1.3
Petroleum Refining	13,185	23,368	17,935	29,349	23,164	1.7	1.2
Chemicals	10,283	22,770	15,884	28,848	21,122	2.2	1.5
Other Manfg.	104,367	235,912	160,468	302,703	224,436	2.3	1.6
Construction	51,747	90,893	70,933	110,045	90,989	1.6	1.2
Air Transport	2,961	8,469	5,288	11,426	7,570	2.9	2.0
Water Transport	2,880	6,239	4,410	8,135	5,306	2.2	1.3
Rail Transport	5,235	11,404	8,022	14,799	10,204	2.2	1.4
Truck Transport	5,199	11,118	7,821	14,406	10,154	2.2	1.4
Bus (Inter-Urban)	381	1,252	744	1,686	1,077	3.2	2.2
Urban Transit	1,136	3,916	2,290	5,290	3,335	3.3	2.3
Pipeline Transport	1,091	1,494	1,226	1,446	1,133	0.6	0.1
Utilities	7,151	14,823	12,444	21,317	18,233	2.4	2.0
Commercial and Other	142,213	326,624	218,252	433,136	302,070	2.4	1.6
TOTAL	482,085	1,020,132	723,899	1,316,930	962,976	2.2	1.5

TABLE 2.3

PROJECTIONS OF SELECTED ECONOMIC VARIABLES

Part A: Growth Rates (%/a)

Scenario and Year	Population	GDP*	GDP/capita	Economic Output	Labour Productivity
Business as Usual					
1978 to 2000	1.3	4.3	3.0	3.5	1.4
1978 to 2025	1.0	2.6	1.6	2.2	1.1
Consumer Saturation					
1978 to 2000	1.3	2.6	1.3	1.9	1.5
1978 to 2025	1.0	1.9	0.9	1.5	1.2

Part B: Absolute Levels

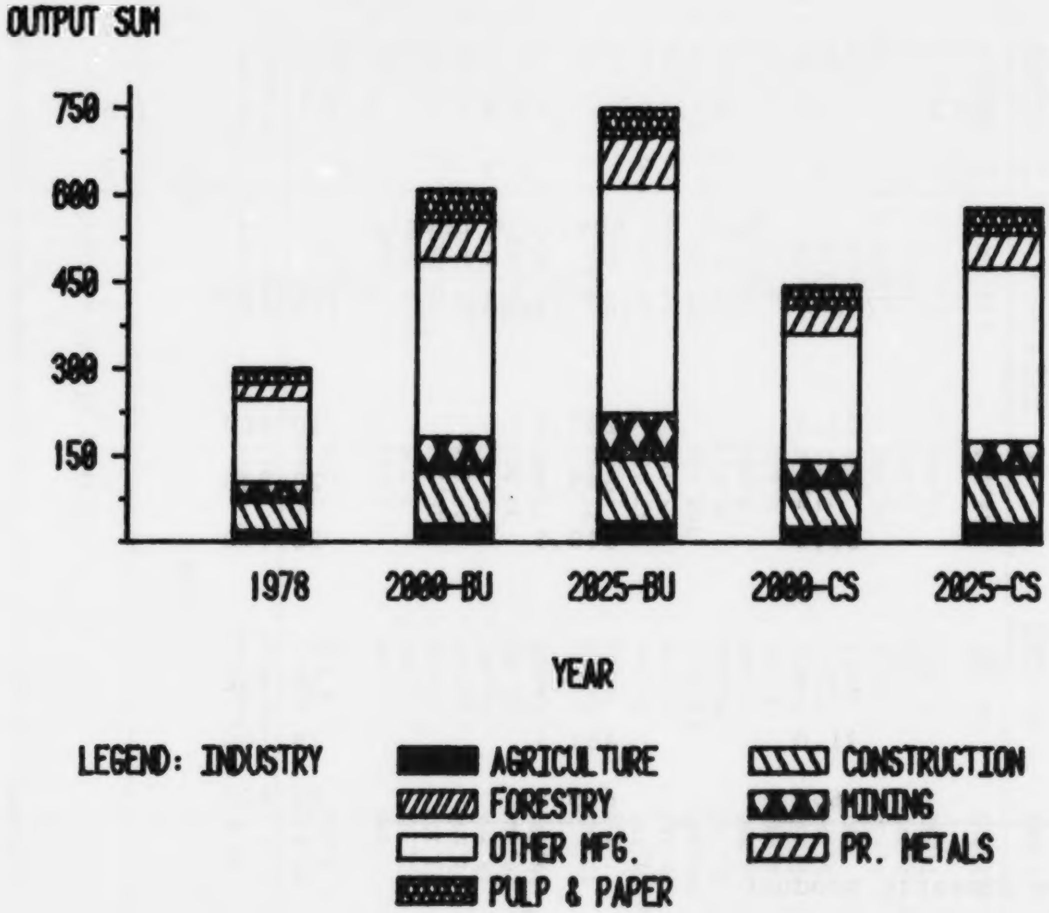
	Population (10^6)	GDP (10^9 1980$)	GDP/capita (1980$)
Business as Usual			
1978	23.5	257.2	10 960
2000	31.0	649.1	20 880
2025	36.9	840.1	22 770
Consumer Saturation			
1978	23.5	257.2	10 960
2000	31.0	451.1	14 580
2025	36.9	619.8	16 800

* gross domestic product

FIGURE 2.2

PROJECTED ECONOMIC GROWTH BY INDUSTRY GROUP

(BILLIONS OF 1980 DOLLARS)



BU = BUSINESS AS USUAL SCENARIO

CS = CONSUMER SATURATION SCENARIO

uses in both scenarios in a way that attempted to balance cost effectiveness and soft path criteria. As with the demand analysis, provincial research teams were free to introduce wider variations in the Consumer Saturation than in the Business As Usual scenario, but in many cases the two scenarios were treated identically on the supply side.

It is important to recognize what the two LTSM scenarios define, and what they do not define, so far as our study is concerned. To a considerable degree the demand half of the study can be seen as working out the implications of equations of the following form for each industry:

$$\frac{E_{i,j}}{E_{i,1978}} = \phi \frac{A_{i,j}}{A_{i,1978}}$$

where

E = physical use of energy (in joules) for industry i in the year j or in 1978

A = value of activity (in constant 1980$) for industry i in the year j or in 1978

ϕ = the ratio of energy intensity (energy use per unit of activity) in the year j to energy intensity in 1978

i = one of the 24 LTSM industries

j = 2000 or 2025

The LTSM scenarios provide us with information about the ratios of activities in 2025 (or 2000) compared with those in 1978, as measured by value of output (in dollars of constant value -- ie. dollars unaffected by inflation). They tell us nothing about the use of energy per se nor about potential changes in the efficiency with which energy is extracted or used. What was done in this study was to merge this information about activity ratios with information about energy use in 1978 and with an estimation of the change in energy intensity over time in order to derive a figure for energy use in the years 2000 and 2025. The sum of these figures over all industries provided an estimate of energy use for all those sectors covered by LTSM in each of two years and each of two scenarios. However, the LTSM does not provide any internal projection for what are called "final demand" sectors, which for our purposes include the residential buildings, private automobiles and government operations. (Residential and government construction are included in the LTSM.) Energy use in these sectors had to be projected in consonance with, but independently from, the LTSM scenarios and then added to the scenario results in order, finally, to obtain projections, by province and by scenario, for energy use in Canada in 2000 and 2025.

In a number of cases provincial research teams made adjustments in the results derived from the LTSM. As noted above, New Brunswick and Newfoundland effected a trade of population and economic output in such a way as to maintain the internal consistecny of the LTSM but distribute activity differently between the two provinces. In other cases, declining industries were not allowed to grow as fast as projected by the LTSM or expanding industries were allowed to grow faster. Balance was maintained either by adding output to (subtracting it from) the same industry in another province, or, if this was not possible, adding output (subtracting it from) other industries within the same province. In the two territories, the large number of zeroes in the LTSM (because many industries did not exist there in 1975) required enough intervention to quite violate the consistency of LTSM results. Fortunately, the scale of activity remains so small relative to that of Canada as a whole that no serious error is thereby introduced.

As indicated above, this approach offers the enormous advantages of being sure that the projected economies will actually "work"; they are internally consistent. However, in order to obtain this consistency, a number of attractive soft path options, particularly in transportation, could not be developed. Certain other changes, as with a greater degree of recycling, had to be introduced rather awkwardly in terms of greater energy efficiency rather than more directly as lower materials consumption. While in principle, some of these changes could have been introduced and the whole LTSM re-run, there was neither the time nor the budget for such refinements.

A further problem is the lack of feedback from the LTSM results on energy utilization for the future to the energy supply sectors built into LTSM (Mineral Fuels, Petroleum Refining etc.). Again, ideally, the model would have been re-run using the different energy supply industries that arose out of our analysis. Failing that, it was not possible to integrate the study-determined Energy Supply sector with that of the LTSM. Instead we simply ignored the LTSM-projected outputs for these industries and built them up on the basis of the actual demands for their production that resulted from our analysis. While this had the great advantage that our Energy Supply sector is related directly to the Energy Supply and demand scenarios used in our study, it introduces a lack of consistency into our model projections. In discussion with Structural Analysis Division personnel within Statistics Canada, however, we were informed that the Energy Supply sector in the LTSM is only loosely tied to the rest of the model through material flows and that it can thus be analyzed separately without doing too much violence to the consistency of the model.

Despite these and other difficulties, it is felt that use of the LTSM makes this soft path study for Canada unique. No other study of which we are aware is built upon so solid an economic base, nor one that offers and works through two scenarios so distinct. Above all, the LTSM allowed researchers to focus their concerns on the energy portion of the economy and on potential gains in efficiency.

Pricing and Costing

It is a fundamental principle of soft path studies to treat all energy as if priced at its long-run marginal cost or at its replacement value (two terms that we treat as equivalent for the purposes of this study). In this way all forms of energy, new and old, renewable and nonrenewable, are treated equivalently, as are investments in energy conservation (valued in terms of avoided expenditures to buy energy) and those in new energy production. (It is unfortunately common to compare the cost of conservation and of new renewable forms of energy not with the cost of new conventional energy but with current costs or the average cost of energy developed in the past, which is not the relevant criterion for future investment.) For much the same reasons, energy is measured at its cost when delivered to the consumer, for only the delivered cost permits a fair comparison with the opportunities to cut energy use (e.g. by adding insulation) or to produce energy on site (e.g. with a solar collector).

Estimates of delivered marginal costs for conventional sources of energy were obtained from an EMR paper (Energy, Mines and Resources, Canada, Economic and Policy Analysis Sector, 1980). These estimates represent what might be called commercial costs in that they incorporate all those costs that would be paid if we had a reasonably free market in energy sales. For a variety of reasons, including the subsidies embedded in current energy pricing and costing, these "reference" costs are higher than the energy costs actually faced by energy users today. Our analysis thus assumes that an economically efficient pricing regime for conventional energy resources is in place, and that decisions are based on those prices rather than on today's prices. Put another way, our analysis is based as far as possible on the real long-run cost of these energy resources. However, no attempt has been made to incorporate social or environmental costs, even though both are known to be widespread and high. Because such evidence as exists (Battelle, 1978; Chapman, 1979 and 1982; Holdren et al , 1980) suggests that subsidies on the one hand and environmental and social costs on the other are far more significant for conventional, centralized nonrenewable forms of energy than for conservation or for most decentralized, renewable forms, it is a significant conservatism to ignore these costs in this study. That is, a full accounting would likely suggest that the former are relatively more costly, and the latter relatively less so, than indicated by the comparisons adopted for the purposes of our analysis.

Finally, as implied by our comments on replacement costs above, we have accepted that the value of depletable natural assets -- oil in the ground, river valleys that can be dammed and so on -- are adequately measured by market-determined prices and costs. That is, the value of the oil or the hydropower is determined by its cost of production discounted at 7% per year to the present. While one can challenge this proposition on a number of grounds (Daly, 1977), any alternative would make it impossible to compare our results with those of most other energy studies.

In order to deal with dollar figures over time, a couple of factors must be taken into account. First, the effects of inflation must be eliminated so that a dollar spent retains its purchasing power from one year to the next. This is accomplished in this study by presenting all calculations and results in 1980 dollars. Such a practice ignores some second order effects but is sufficiently accurate for our purposes. In addition, adjustment must be made for the fact that there is an interest cost for the use of money, which cost reflects the fact that money can be invested and earn money, even after eliminating the effects of inflation. A number of discount rates, as this factor is called, have been suggested as appropriate, but modern views centre around values of about 7% real per year. Inasmuch as this was one of the rates used in the EMR pricing paper referred to above, it was selected as a uniform discount rate for all calculations. The combination of inflation rates and discount rates means that, if at some point the rate of inflation was 10%, an investment would have to earn at least 17%[1] to be worthwhile since the 7% discount rate applies only after the effects of inflation have been eliminated.

Table 2.4 and Figure 2.3 show the projections for crude oil, natural gas and electricity costs used in this study. The projections for real cost increases were escalated from EMR figures for 1978. Essentially, for natural gas and crude oil real cost increases of 3% per year were assumed for 1981 to 2000, and of 1.5% per year thereafter; for electricity real cost increases of 2% per year were assumed from 1981 to 2000, and of 1% per year thereafter. (The possibility exists that the cost escalations, especially for natural gas, may be too high. However, it should be noted that our analysis depends much more on the prices in 2000 and 2025 than on fluctuations in prices in intermediate years. That is, the same prices assumed in our study for 2000 and 2025 could also result from lower escalation rates in intermediate years coupled with several abrupt price

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[1] Precisely, it would have to earn 17.7% (10% + 7% + (10%) (7%)).

TABLE 2.4:

REFERENCE COST PROJECTIONS FOR CONVENTIONAL FUELS

(all costs in constant 1980 dollars)

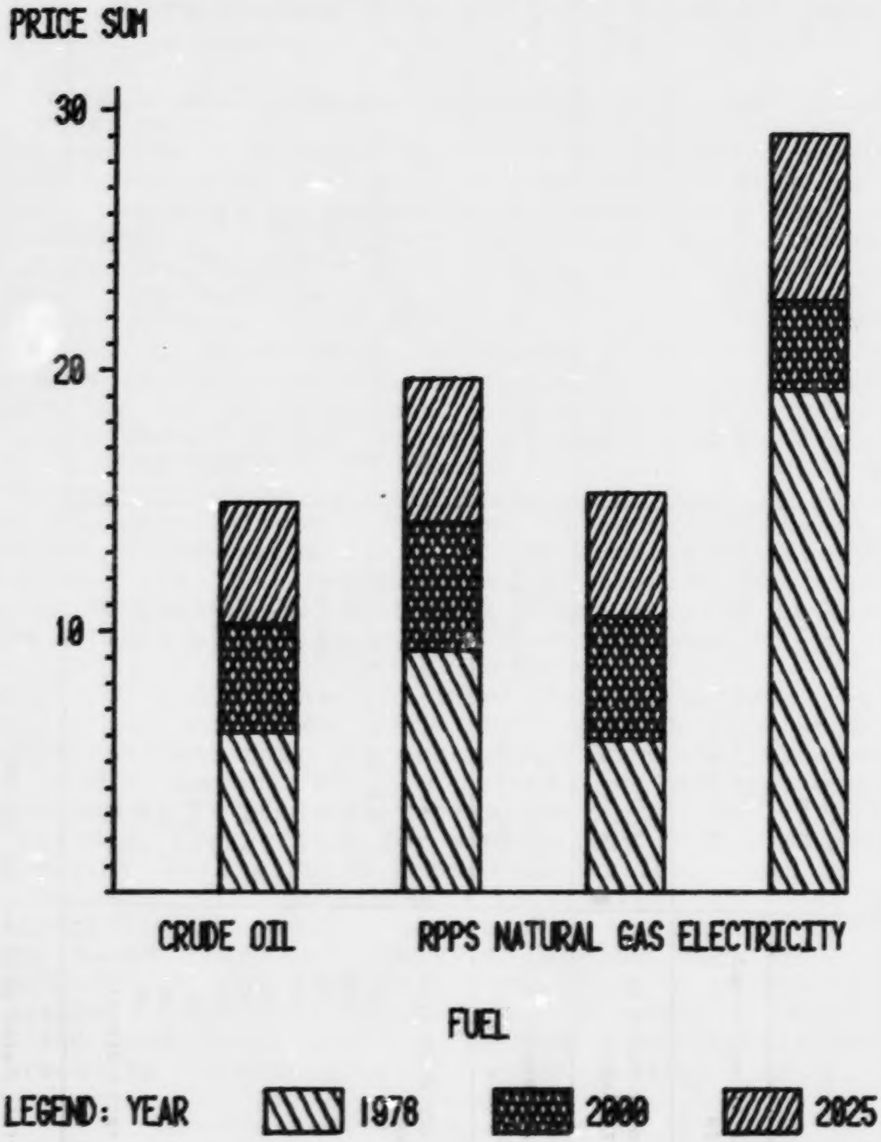
	1980		2000		2025	
	Natural Units	Energy Units	Natural Units	Energy Units	Natural Units	Energy Units
Crude oil at well-head in Alberta	$235/m^3 ($37/bbl)	$6.11/GJ	$394/m^3 ($63/bbl)	$10.28/GJ	$572/m^3 ($91/bbl)	$14.91/GJ
Petroleum products at Alberta refinery	32¢/L ($1.47/gal)		49¢/L ($2.24/gal)		68¢/L ($3.08/gal)	
Natural gas anywhere in Canada	$217/m^3 ($6.15/Mcf)	$5.83/GJ	$392/m^3 ($11.11/Mcf)	$10.53/GJ	$569/m^3 ($16.12/Mcf)	$15.28/GJ
Electricity delivered to consumer						
NF	6.24¢/kW.h	$17.33/GJ	9.27c/kW.h	$25.75/GJ	11.89c/kW.h	$33.03 /GJ
PE*	13.49	37.47	9.21	25.58	11.81	32.81
NS*	10.11	28.08	9.21	25.58	11.81	32.81
NB*	10.38	28.83	9.21	25.58	11.81	32.81
QU	4.35	12.08	6.46	17.94	8.29	23.03
ON	4.35	12.08	6.46	17.94	8.29	23.03
MN	6.31	17.53	9.38	26.06	12.02	33.39
SK	4.73	11.75	7.03	19.53	9.01	25.02
AB	4.45	10.97	6.61	18.36	8.48	23.56
BC	5.79	16.08	8.60	23.88	11.03	30.63
Off-grid diesel	10.18	28.28	18.39	51.08	26.68	74.11

* Fully integrated grid assumed by 2000.

FIGURE 2.3

PROJECTED ENERGY PRICES

(1980 DOLLARS PER GIGAJOULE)



CRUDE PRICE IS AT ALBERTA WELLHEAD
RPPS PRICE IS AT AN ALBERTA REFINERY

NATURAL GAS PRICE IS FOR ANYWHERE IN CANADA
ELECTRICITY PRICE IS AVERAGE OF PROVINCIAL PRICES

increases over the study period.)

For crude oil, the main assumption is that the world price of crude oil represents the opportunity cost of crude oil for Canada. After making adjustments for quality and for locational factors, a wellhead reference cost in Alberta of $\$250.78/m^3$ ($\$34.71$/bbl) is obtained, but to this figure EMR adds a premium of $\$18.64/m^3$ ($\$2.58$/bbl) to cover the cost of establishing a storage system as insurance against import cutoffs. This then became the wellhead reference cost for 1980, as shown in Table 2.4, and to this figure each province had to add transportation costs as appropriate. The price was escalated to 2000 and 2025 as indicated above, except that by 2000 the security of supply premium was phased out; prior to that time our sources of supply would have become entirely domestic. Costs for petroleum products were estimated assuming 5% losses and refinery costs of 7.7¢/L (35¢/G) on top of crude prices.

Turning to natural gas, costing is based on the assumption that, if not used domestically, the gas could be exported at a price equal to the joule-equivalent price for crude oil. This gives a Toronto city-gate price of $\$217/m^3$ ($6.15/Mcf) in 1980, but, in contrast to oil, this price is the same in all parts of the country inasmuch as its export value is the same everywhere. This assumption is not entirely satisfactory as it is equivalent to assuming zero transportation costs, but it does reflect value (oil equivalent in energy terms) at point of use. A further problem is that natural gas is not a perfect substitute for oil, but, in the absence of setting different prices for each end use, no general way was found to cope with this difficulty.

Electricity costing caused more difficulties, both because long-run marginal costs differ among provinces and because, in contrast to oil and gas, we did not accept EMR's estimates of costs in 1980 (though we did accept the Department's method for calculation). In particular, we find good evidence that generating costs for nuclear power (the marginal source of supply in all provinces except Saskatchewan and Alberta) are not $0.014/kW.h as taken by EMR but at least $0.028 (Gibbons, 1981; see also Chapman, 1982).[2] In addition, generating costs for the large coal-powered plants considered to be the marginal source in Saskatchewan and Alberta make no allowance for royalties on coal, an assumption which implies the coal has no value in the ground, so a value equivalent to a charge of $0.05/kW.h was added as of 1978 and escalated with electrical prices thereafter. The reference costs shown in Table 2.4 for electricity include these two adjustments (which were, of course, applied only to the base load portion of electrical demand in each province). No other adjustments were made to the EMR reference costs for electricity. That is, transmission and distribution costs and load factors were taken as given, as were the costs of intermediate load and peaking power and the assumption of a grid in the Maritimes (to take advantage of economies of scale). Off-grid costs for diesel-generated electricity were also calculated according to the EMR method.

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[2] This figure assumes a 7.0% real discount rate and an 80% system load factor. Gibbons (1981) found that the Ontario Hydro figures used in the EMR study are based upon many questionable assumptions but in particular they do not allow adequately for the use of capital or the cost of heavy water.

One additional special consideration was critical for electricity and this involved peaking problems.[3] In principle, people who invest heavily in either insulation or in solar heating systems (or in small wind or photovoltaic systems) could impose a heavy load on the utility during the winter months if they rely upon electricity as a back-up to maintain air and water temperatures. The load factor for such houses could easily be less than 30% representing use in November through January, which, given that electrical utilities in Canada are winter peaking, would require large excess capacity the rest of the year. Although the excess capacity so created would likely be less than with houses using conventional electrical resistance heating, it still creates a Catch-22: on the one hand, for some situations electricity is an appropriate backup; on the other, if such units are charged as they should be for a low load factor, the cost of electricity would be so high that no one would use it. In the worst case, the peak demand could remain almost as high but become much narrower (Mueller et al, 1981). To resolve this dilemma, those units requiring electrical back-up were charged at the same rate as other customers, but care was taken in designing provincial grids to ensure that excessive seasonal peak loads were not imposed on the utility. This issue is discussed further in Section 2.5 below.

In summary, the reference costs for crude oil, petroleum products, natural gas and electricity, as determined by methods described above and as displayed in Table 2.4, became the point of comparison for investments in soft energy alternatives, including both conservation and renewable sources of supply. Specific information on the economics of these technologies will be presented below in this chapter. For the moment, it is important only to add that they were evaluated on a life cycle basis and that, where enough information was available, appropriate cost comparisons were developed by use of the following formula:

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[3] A special study was undertaken to investigate the impacts of solar space and water heating and of solar electricity on the peaking characteristics of utilities. Appendix 2.3 contains a list of supplementary studies undertaken in connection with this study.

$$\text{Annual Cost} \quad \frac{I(i)}{1-(1+i)^{-n}}$$

where

I = initial investment;
i = discount rate; and
n = amortization period

That is, when using this formula, the annual cost of a conservation or renewable technology had to be less than the reference costs of conventional fuels for an equivalent amount of energy in order for that technology to be considered cost-effective. More often, however, given the paucity of information, simple payback criteria had to be used. In such cases, the criterion for cost effectiveness was set at a maximum three-year payback for industry and at a maximum ten-year payback for households. In all cases, of course, the 7% real discount factor was applied. In no case was unproven technology introduced, though some techniques that are not cost-effective at 1980 costs were. That is, in certain cases (e.g. solar water heating) where there was reason to expect cost reductions, soft sources were introduced as they became cost-effective in the future.

2.3 THE ENERGY BASE OF THE STUDY

Statistics Canada Catalogue 57-003 (Quarterly Report on Energy Supply-Demand in Canada) is the basic source of energy information for our study. Coupled with other Statistics Canada reports,[4] 57-003 provided a reasonably consistent set of energy source and use data for 1978, which was in effect the energy term in the basic formula for projection as described above. In addition, when divided by output, scale or other information, the energy statistics in 57-003 could be converted into estimates of energy efficiency by sector and subsector.

Of course, as with most energy statistics, those presented in 57-003 are far from ideally designed for a soft energy study. In particular they do not show energy use by thermodynamically relevant categories (heat at various temperatures, portable liquids, etc.) Since soft energy path analysis requires that energy use be disaggregated into quality categories, an independent analysis was undertaken in order to allocate the secondary use numbers derived from 57-003 into the four quality categories used in this report (Heating and Cooling, Process Heat, Liquid Fuel and Electricity Specific - see the Glossary). The results of that analysis are shown on Table CA-1 of Chapter 3.1. A related problem stems from the growing need in statistical compilations to keep track of flows of energy quality as well as of quantity; otherwise there is great risk of double counting when dealing with cogeneration, district heating or other forms of energy cascading. At present no statistical compilation deals very adequately with this problem. Finally, 57-003 shows energy use only in secondary units; that is total energy use as purchased by consumers. No information is available there as to tertiary energy use, that is the amount of useful work actually accomplished by the use of energy (equivalent to secondary use multiplied by the efficiency of the end-use device). In principle, a soft path study should be conducted at the level of tertiary use but in practice this could only be done for buildings. As a result, all information for this study is displayed in secondary units.

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[4] The other reports included mainly the following: 53-215, Passenger Bus and Urban Transit Statistics; 53-222, Motor Carriers - Freight and Household Goods Movers; 57-205, Gas Utilities (Transport and Distribution Systems); 57-218, Road Motor Vehicles (Fuel Sales); 52-210, Railway Transport (Part IV - Operating and Traffic Statistics); 54-002, Shipping Statistics; 51-001, Transcontinental and Regional Air Carrier Operations.

Other difficulties arise from (1) problems in the categorization of certain data within 57-003 itself, and (2) the need to merge the sectors into which 57-003 is divided with the similar but not equivalent sectors in the LTSM and in other sources of information. Both problems deserve explanation.

Adjustments were made in the 57-003 data to accomplish the following. First, all transportation data (some of which currently appears as commercial or government use) was moved into the Transportation sector.[5] Second, because 57-003 separates out both the Energy Supply sector's use of its own products, and non-energy use, from its energy use totals, it was necessary to allocate those amounts into the appropriate industries, in order to show the total use of energy products by those industries. For example, the refined petroleum products used by the refining industry to produce other refined products are shown separately in 57-003 and had to be added to the total use of that industry. Similarly, the use of asphalt (to pick one non-energy product) was shown separately and had to be allocated to the appropriate industry. In general these allocations were done on the basis of consultation with the relevant Statistics Canada officials.

Third, LPGs were unallocated in 57-003 for 1978. This allocation was performed on the basis of prorated percentages derived from the 1979 issue of 57-003, which contained those allocations, but which was published too late to be used as the basic source of energy data for our study.

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[5] The source of this problem lies in the fact that transportation is not a sector in the same sense as residential, commercial, and industrial; rather it is a way of using energy. At present most transportation is identified separately but a little is distributed among the Industrial and Commercial sectors.

Fourth, in accordance with Statistics Canada practice, where coke use serves the dual role of reductant and high temperature energy source (i.e. primarily in steel making), 50% is categorized as non-energy use and the other half as high temperature process heat.

An even greater difficulty with the energy use data was occasioned by the need to "map" use sectors as displayed in 57-003 onto those displayed in the LTSM. This problem was complicated by the fact that we also relied for information on the Federal Government's Industrial Energy Conservation Task Forces which in turn are divided into sectors somewhat different from those in either 57-003 or the LTSM. The actual mapping used is shown in Appendix 2.4. However, the mapping itself, though essential, does not solve the problem, for energy statistics must be found that conform, ultimately, to the arrangement in the LTSM (i.e. to the format that is projected through time), and it thus required a very wide search for data that could not be obtained from 57-003. In addition, it was difficult to get good data on industry, as will be described at greater length below.

A related problem arose from the inadequate definition of sectors in both LTSM and 57-003. This is not so much a problem for projection per se when less detail is something of an advantage, but it is a problem for estimation of energy efficiency. This was the heart of the industrial problem referred to just above, and it is almost as serious for commercial activities (which comprise everything from corner groceries to shopping centres and from neighbourhood schools to skyscrapers). A variety of additional sources of information had to be used (and checked against local or provincial data). For example, a report to the National Research Council on the potential for solar water heating provided a breakdown of the Commercial sector according to seven building types on a regional basis (Middleton Associates, 1981).

Finally, no account was taken of embodied energy (that is, the energy content contained in goods) in this study except with respect to petrochemicals and other non-energy products. At present, the energy content of, say, steel is attributed to the province where the steel is made, not where it is used. While this makes little difference to the totals (except in the case of imports and exports), it does affect the allocation of energy demand. However it was deemed more appropriate to analyze energy use in terms of the industrial categories within which the direct use took place.

2.4 DEMAND ANALYSIS

Soft energy studies all begin with analysis of demand, not supply. The objective is to identify the nature and extent of human services demanded of energy. Only later is it worth looking for sources of supply to satisfy those demands. In addition to this point of principle, it turns out to be more convenient to treat certain technical changes as means of reducing demand rather than of increasing supply. For example, passive solar heating can be separated only in part from other changes in building design, and it is generally simpler analytically to incorporate it into the demand analysis than to view it as an alternative soft source. This section of the chapter will outline general aspects of our demand (or, more accurately, end-use) analysis in each of the major consuming sectors. As indicated above, the size of the sectors, relative to today, was derived from the two LTSM projections (Business as Usual and Consumer Saturation). Hence, our analysis could focus on the derivation of efficiency levels for 1978 and the projection of these efficiency levels to 2000 and 2025.

Residential Sector

The Residential sector is not obtained from the LTSM projections (nor is household use of automobiles), but is derived from population projections and provincial information on household formation, housing stock and construction patterns. In general, these data show slowly growing population combined with decreasing persons per household and less living space per household (resulting from a shift toward multiple family housing). In our analysis, new housing was separated from old and both were divided into the following categories: (1) single family detached; (2) attached units, duplexes and row houses; (3) apartments; and (4) where relevant, mobile homes. Much of the housing required by 2000 and even by 2025 is already built, so as much attention must be paid to energy efficiency in existing as in new housing.

Given the rapid spread of information on energy efficiency in buildings, it was logical to adopt some national "standards".[6] (As we use the word "standard" here and elsewhere, the word does not refer to a legal prescription or regulation but to a goal toward which technology is moving across the country as a whole. However, the rate at which various provinces and territories move toward that goal is left open for independent determination on a region-by-region basis.) For new housing, it was assumed that housing built using low-energy approaches pioneered in Saskatchewan (Besant et al, 1979; Lange, 1980) will become the norm by 2025, which yields a standard of 30 to 35 GJ per year for total energy use divided into 12 GJ for space heating, 12 GJ for water heating and 6 to 10 GJ for electricity specific uses (Soft Energy Notes, 1980; Solar Energy Research Institute, 1981, Chapter 1; Buesing, 1981). Some of those uses here incorporated into the electricity-specific category (e.g., cooking, refrigeration) really involve movement of heat and are therefore excluded from this quality category in most soft path studies. Our categorization is intended to reflect both the availability of hydro-electricity and the widespread use of electricity for these purposes in Canada.

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[6] Our calculations, including links to form of energy and type of furnace, were greatly aided by use of a computer model developed by Dr. William Ross, author of the Alberta chapter in Volume II, at the Faculty of Environmental Design, University of Calgary.

The results for residential space heating depend mainly upon high levels of insulation, air-tight construction, air-to-air heat exchangers and passive solar design. Efficiency gains for water heating come exclusively from simple approaches such as greater insulation and flow restrictors.
The use of energy for electricity specific applications in residences (Table 2.5) allowed for increasing saturation levels, and was developed according to the analysis of Norgaard (1979, 1980; see also Goldstein, 1981).[7] The projected energy savings for new housing may appear great, but they are already being achieved and are so highly cost effective (16% real and tax-free rate of return) that ECOSB officials expect that new housing built in 1990 will show a 60% saving compared with that built in 1980 (Armstrong, 1981; see also Dumont and Orr, 1981; Ficner, 1981; Brandt and Holtz, 1982).

For the improvement of energy efficiency in existing buildings (generally called "retrofitting"), the minimum saving was taken to be 50% of today's energy use for those buildings still standing in 2025 (that is, after eliminating demolitions). This is an exceptionally modest goal given that ECOSB officials estimate that 45% savings will be cost effective by the 1990s (C. Ficner, personal communication, 1980) and given the results of U.S. studies (Solar Energy Research Institute, 1981, Chapter 1). An early study done for CMHC (Scanada, 1976) indicated that 37% savings were possible with simple retrofit measures, and furnace retrofits or replacement can add 20% savings on top of this. A more recent study done in British Columbia and based on simulation results for individual houses, estimated that 50% savings for space heating fuel are possible using simple measures that are cost-effective against the delivered cost of new electric space heating systems (Solar Applications and Research Ltd., 1981). Moreover the "house doctor" approach developed at Princeton University has demonstrated savings of between 60 and 70%

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[7] A special study of appliance and lighting use was undertaken; see Appendix 2.3.

TABLE 2.5

PROJECTED ELECTRICITY SPECIFIC USE IN RESIDENCES IN 2025

	Annual Energy Use		
	Per Appliance	Per Household	Saturation
Appliance	(kW.h/a)	(kW.h/a)	(%)
Refrigerator	190	190	100
Range	440	440	100
Microwave Oven	150	100	67
Microwave Oven*		-103*	67
Heat Distribution Fans	640	640	100
Freezer	70	70	100
Dishwasher	58	46	80
Television	90	135	150
Clothes Dryer	166	133	80
Washing Machine	75	68	90
Lighting	225	225	100
Small Appliances/ Stereo	150	150	100
Car Block Heater	140	140	100
Car Interior Warmer	200	120	60
Air Conditioner	500	10	2
"Dieux Inconnus"**	400	400	100
TOTAL		2764 kW.h/a or 9.95 GJ/a	

Source: adapted from Norgaard (1979).

* credit for reduced use of range

** (electronic games, air filtration, home computers, etc.)

(Ross and Williams, 1980; 1981, pp. 121-3), and with complete gutting and/or new siding, savings can be as great as with new housing.

A couple of special problems arise when dealing with residential structures. Mobile homes are notoriously inefficient, and it is not generally possible to make improvements in them to the same extent as in permanent structures. The question of back-up for housing units built to Saskatchewan House standards becomes a problem as annual use would be too low to amortize a gas line. Apart from fuels that can be delivered in storable forms (eg. wood or bottled gas), electricity becomes the system of choice, provided seasonal peaking problems do not make it too expensive.

Commercial Sector

The problem posed by the Commercial sector is not merely that it is diverse -- after all, the industrial sector is far more diverse -- but that, so far as the statistics go, it is almost totally undifferentiated. The sector includes a wide range of activities and structures in the tertiary (service) part of the market economy as well as schools, hospitals and government buildings. For the purposes of this study, commercial activity at the subsectoral level (apart from government operations) was projected independently by assuming it maintained a constant share of the gross provincial product over time. Where possible, the sector was broken down into the following subsectors: offices; schools and universities; hospitals; stores and shopping centres; hotels and motels; restaurants; government; and street lighting. Unfortunately, in many cases the bulk of energy use had to be left in a final category, viz. unallocated. Given that the weighted average growth among the subsectors had to equal the growth of the commercial sector as projected by LTSM, it was possible in some provinces to take that total and allocate downward by subsector.

Finding energy data on the Commercial sector is as difficult as finding economic data. Some appears in 57-003, but it is inadequate in terms of detail. Moreover, it is almost impossible to relate gross data on energy use to any measures (such as floor area or output) that would permit a calculation of energy efficiency. Much of the information on efficiency had to be locally gathered, but for large buildings with HVAC (heating, ventilating and air conditioning) systems, national standards were set, as follows: By 2000 all new office buildings were assumed to be meeting an energy use level of 100 kW.h./m^2 for HVAC systems plus lighting, and by 2025 a level of 50 kW.h./m^2. (As with residences, passive solar design, where appropriate, is included in these figures.) These efficiency levels were then each multiplied by 1.5 based on experience in Canada to allow for the additional energy use specific to building occupants -- everything from coffee pots to computers. Judging by the Gulf Canada Square building in Calgary, the year 2000 standard is cost-effective today, and the LEBDA design competition indicates that the year 2025 standard is quite within reach (Public Works Canada and EMR, 1980; Harding, 1981; Solar Energy Research Institute, 1981, Chapter 1). For retrofits of buildings existing in 1978, savings of 25% are deemed cost-effective almost immediately, rising to about 50% by 2000 and about 67% (for those buildings still standing) by 2025 (Dubin, 1978; Ross and Whalen, 1980; Armstrong, 1981). This conforms to an analysis by ECOSB which shows about 48% savings expected in buildings in this sector by 1990 (C. Ficner, personal communication, 1980; see also Solar Energy Research Institute, 1981, Chapter 1).

It was assumed that the more efficient new large buildings became, the more likely they were to be all-electric. Their direct energy requirements for heating are zero, and with good design the air conditioning load can be sharply reduced; hence, the great bulk of residual demands are logically in the electricity specific category. However, in some cases the electricity could be locally generated, as in total energy systems or by photovoltaics (in the latter part of the period under study), if some nearby use for the waste heat generated in those systems could be found.

National standards were also set for improvements in the energy efficiency of street lighting. Most communities have plans for converting from incandescent and even mercury vapour to sodium vapour systems. The gains are expected to be 40% (compared with 1978) by the year 2000 and 60% by 2025 (Lang and Armour, 1980).

The potential for improvements in other subsectors of the commercial sector is so variable from place to place and from institution to institution (as are the existing levels of energy use) that national standards were avoided. However, case studies such as those developed by Ontario Hydro (see its newsletter Energy Management) and at ECOSB provided considerable guidance.

Industrial Sector

The industrial sector presented our study, as it has every other soft energy study, with its greatest statistical and conceptual problems. While it is easy to estimate enormous potential savings in single subsectors, it is anything but easy to prepare a consistent set of such estimates across subsectors. One is trapped between generalizations, in which case the clear linkage between specific investments or techniques and energy savings is lost, and an extended investigation of every subsector and every technology, which takes far too much time.

Our study opted for a mix between generalization and precision. The basic projections of industrial growth were derived from the LTSM using 16 subsectors (including agriculture and construction), which highlighted the major energy using industries. The 16 subsectors define an exhaustive set, as follows: agriculture; forestry; fishing, hunting and trapping; iron mines; mineral fuels; other mining; food processing; pulp and paper; iron and steel; smelting and refining; cement; petroleum refining; chemicals; other manufacturing; construction; and electric power, gas and other utilities.[8] Adjustments to convert to 1980 dollar outputs were made using industry selling price indexes.

Statistics on energy use in 1978, and hence of sectoral energy efficiency, were developed from information in 57-003. Estimates of a reasonable level of savings between 1978 and 2000 and 2025 was derived from still a third source of information, the Federal Government's Task Forces on Industrial Energy Conservation (Wolf, 1978). In an admittedly crude procedure, rather at variance with that adopted for other sectors, goals that the Task Forces had established for energy conservation to 1985 were extended in a relative sense to 2025. That is, annual percentage gains in efficiency were held constant which means that, with a declining level of total energy use per unit of output, absolute efficiency gains continue but get smaller and smaller over time. Table 2.6 shows the results of this procedure, which, over all industry, yields energy savings of 62% per unit of output.
These savings, as it turns out, are quite comparable to those shown in other recent studies (Messenger, 1981; Solar Energy Research Institute, 1981, Chapter 2), even if unfortunately for undefined reasons.[9] The results are also comparable with those of a detailed Swedish study which found that overall energy savings in industry of 50% per unit output could be obtained if Swedish industry adopted the best technology currently available, and of 60% with more advanced technology. The former was judged likely to become "average" technology by 2000 and the latter by 2010 even without further real price increases for energy (Johansson et al , 1982). Because the main energy consuming industries in Sweden are already (depending upon whose statistics one accepts) 10 to 35% more efficient than their counterparts in Canada, expected gains from the Swedish study turn out to be very close on an industry-by-industry basis to those from our study.

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[8] The three energy supply industries included here were analyzed separately, as discussed below.

[9] It is worth noting that the creators of the LTSM themselves used the Industrial Task Force projections in order to run a sub-scenario of the model that incorporated increased industrial energy efficiency (McInnis and Trepanier, 1979, p. 6).

TABLE 2.6:

INDUSTRIAL CONSERVATION TARGETS

Industry Task Force Group		Average Annual Percentage Change in Intensities[1] 1972-1985	1978 Intensity[2] GJ/10^6\$(1980)	Projected Energy Intensity[3]			Cumulative Percentage Savings in Intensity in		
				1990	2000	2025	1990	2000	2025
1.	Chemicals	-2.81	17,886	12,705	9,554	4,685	29%	47%	74%
2.	Electrical & Electronic	-2.30	3,500	2,647	2,098	1,172	24%	40%	66%
3.	Ferrous Metals	-0.70	19,232	17,677	16,478	13,824	8%	14%	28%
4.	Food and Beverage	-1.95	3,500	2,763	2,269	1,387	21%	35%	60%
5.	Cement	-2.38	80,418	60,231	47,338	25,923	25%	41%	68%
6.	Industrial Minerals	-1.99	3,500	2,750	2,249	1,360	21%	36%	61%
7.	Mechanical Machinery	-2.61	3,500	2,548	1,956	1,010	27%	44%	71%
8.	Mining and Metallurgy	-1.29	34,539[4]	29,556	25,957	18,762	14%	25%	46%
			12,740[5]	10,901	9,574	6,920	14%	25%	46%
9.	Petroleum Refining	-2.19	24,353	18,670	14,961	8,601	23%	39%	65%
10.	Plastics	-2.43	3,500	2,605	2,032	1,101	26%	42%	69%
11.	Pulp and Paper	-2.71	5,266[6]	3,787	2,877	1,448	28%	45%	73%
			15,005[7]	10,790	8,198	4,125	28%	45%	73%
12.	Textiles	-2.90	3,500	2,459	1,832	878	30%	48%	75%
13.	Transportation Equipment	-3.69	3,500	2,229	1,531	598	36%	56%	83%
14.	Wood Products	-0.73	3,500	3,205	2,979	2,480	8%	15%	29%
	Total	-2.06	8,587	6,689	5,432	3,288	22%	37%	62%

[1] Derived from Industrial Task Force Goals

[2] Derived from actual 1978 consumption and LTSM output figures (see Appendix 2.4)

[3] Average annual percentage decline in intensity, 1972-85, extrapolated to target years

[4] Iron Mines

[5] Smelting and Refining

[6] Forestry

[7] Pulp and Paper

Two industrial subsectors, construction and agriculture, had to be dealt with separately. Regional variations made the development of national targets infeasible so individual provincial researchers were left to develop appropriate conservation savings. For agriculture, the intensity savings in 2000 ranged from 17% per unit of output in PEI to 24% in Saskatchewan, and, in 2025, from 23% for PEI to 50% for Alberta. For construction, the intensity savings ranged from 15% to 37% per unit of output for the year 2000 to 25% to 62% in 2025. Again, these savings were comparable to those used in other recent studies (Messenger, 1981; Solar Energy Research Institute, 1981, Chapter 2).

The entire analysis for industry was bedeviled by two severe blockages. First, in most provinces critical industrial energy use data are held confidential by Statistics Canada because of the rules under which they operate. (If there are fewer than three establishments in any industrial subsector, the data for that subsector are not shown separately but only included in the industrial totals.) While few of the firms are really concerned about the release of energy data, it is the rule within Statistics Canada not to release any data identifiable by firm. Second, the Industry Task Forces refused to specify for us the base levels of energy efficiency from which they were projecting their gains. That is, they would tell us that, say, 15% gains between 1980 and 1985 could be expected in such and such an industry, but neither the level from which they were starting nor that to which they were tending. Thus, the need to generalize in the industrial sector was occasioned not only by time constraints but also by severe data constraints.

In moving from the national Industry Task Force targets to provincial calculations of expected savings, the method used was as follows. First, for each province, 57-003 industrial energy use figures and LTSM output figures (converted to 1980 dollars) were mapped on to the Task Force industries according to the relationships specified in Appendix 2.4. This allowed the calculation of province-specific energy intensities for each Task Force industry. These intensities were then projected using the average annual percentage savings derived from the Task Force conservation goals. Finally, the results for 2000 and 2025 of these projections were mapped back onto the LTSM industries to derive provincial energy use numbers for each industry in those years. While this analysis implicitly assumes that the national Task Force goals are applicable to each province, and while this assumption is clearly questionable, given the different industrial processes and age profiles of plants among provinces, no alternative was available. An attempt, under separate contract with EMR, to derive province-specific Task Force goals for each industry soon bogged down because of the unavailability of data mentioned above and the large differences between results reported by the Task Forces and results derived from calculations based on Statistics Canada data (Figueiredo, 1982). Clearly, substantial improvements in the industrial energy use and conservation potential data base are required if more meaningful analysis is to be possible.[10] Fortunately, as noted below, most provincial analysts could buttress the generalizations involved in the projection of industrial efficiency by looking more closely at those subsectors of special relevance to their province's level of energy use.

In general, the aggregate savings resulting from our analysis seemed reasonable relative to process-specific estimates of the long-run conservation potential (see, for example, Messenger, 1981, and the articles in Energy Technology, a publication of the National Swedish Board for Technical Development). In addition, work done by the Industry Section of EMR's Conservation and Renewable Energy Branch provides both general and specific support for the results described above. Broad analysis of industrial energy use in Canada showed that it is indeed the major energy using sector of the economy and that, although it purchases almost all forms of energy, some 90% of this energy is used in the form of heat (James, 1981). Vast quantities of recoverable energy in the form of gaseous and liquid waste streams have also been identified in surveys (Lalonde et al, 1981). Industry of course reacted to the turn-around in energy prices that began in the late 1960s, and over the course of the 1970s energy intensity in Canadian industry was falling by about 1% per year.

Recent studies have begun to demonstrate the links between the savings from specific conservation projects in industry and overall expected sectoral savings. In one analysis the cost-effectiveness of a "representative sample" of 39 industrial conservation projects was determined. Both marginal and average cost curves for conservation were developed, and compared with the marginal costs for production of energy from frontier natural gas, tar sands plants and nuclear electricity (Diener and James, 1981). In almost all cases the supply price of energy saved through the conservation projects was less than that of energy supplied from the new sources. (The range for conservation projects was from about 2¢/GJ to $3.60/GJ but most projects had supply prices below $1; these figures can be compared with those shown in Table 2.4 above. Extrapolated to cover all industries and all intra-marginal conservation projects, it was estimated that industrial energy use would be cut by 27% once the projects are fully implemented.

The 27% estimate for industrial energy savings, as calculated in the EMR study, refers to the period 1980 to 2010. Hence, it can reasonably be compared with the projection of a

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[10] Similar problems have been experienced in the industrial sector analyses of soft path studies in other countries. See, for example, Leach et al (1979) and Solar Energy Research Institute (1981).

37% savings for the year 2000 used in this study. It is unlikely that there is any significant difference between the two numbers because, for a variety of reasons, the Diener-James estimate should be regarded as a minimum. For one thing, their work was based on a report by Acres Consulting Services Ltd. that was significantly constrained by the unwillingness of Task Force members to release the results of individual studies; indeed the original report is yet to be published, and the 27% estimate is itself less than what the Task Forces consider likely for industry as a whole by 1990. (Of course, in contrast to the relatively opaque top-down approach used by the Task Forces, the Diener-James results were built up from the investigation of individual conservation projects.) The Diener-James study also put to one side a number of important areas for industrial conservation that they could not investigate within the limits of their study. The study excluded any equipment, technique or process technology that was not fully developed; it also excluded projects involving cogeneration or the substitution of wood or other wastes for primary energy inputs. Relaxation of any of these limitations would greatly expand the identified conservation potential. Finally, in a subsequent study of mining and metallurgy (more accurately, metal mining and non-ferrous smelting and refining), which were excluded from the original sample but which together account for 14% of industrial energy use, energy savings of 20% were identified through implementation of conservation projects that averaged 80¢/GJ, only one-quarter of the average price of $2.30 for the sample of 39 projects discussed above (James, 1982).[11]

The next problem with industrial data is the need to specify the quality of energy that is being used for use in the supply analysis. Quality data were sought for industrial use of process heat at temperatures of 100^0C. and below (including heating and cooling); at 101^0 to 260^0C., and above 260^0C.; in addition uses that specifically required liquid fuel or electricity were identified.[12] Much of our information on quality was derived from an EMR report on energy cascading in Canadian industry (Lalonde et al, 1981), which distributes industrial energy use for 1976 by form and by thermodynamic quality. In some cases, we were able to supplement this with other information, and, where critical, the data were checked at the provincial level. In the absence of better information, it was assumed that the proportional distribution of energy use by thermodynamic quality would remain the same over time in any industrial subsector. Attempts were made to separate reductions in overall energy use per unit of output and reductions in purchased energy, as by greater use of waste products and residues as energy sources -- techniques that are critically important in the pulp and paper and chemical industries. (The Industry Task Forces reported savings in purchased energy, not in actual energy use.) In addition, special attention was paid to opportunities to re-use rejected heat in the higher temperature ranges (also identified by the Lalonde report cited above) and to introduce cogeneration, which all evidence suggests has an enormous potential (Williams, 1978; Middleton Associates, 1978; American Gas Association, 1981).[13] However, these changes were studied in order to link more closely the projected Task Force savings and specific techniques; they were not added to the Task Force estimates of efficiency gains, which we assumed had, in one way or another, already allowed for use of such techniques.

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[11] In each case the supply price of the savings for each project was weighted by the expected annual savings from its implementation.

[12] A special study was made of the use of medium- and high-temperature heat in industry, as noted in Appendix 2.3. Note that the categorization of energy used to create process heat is defined by the temperature at which it is used. That is, all the energy used to heat steam to, say, 300 C is included in the high-temperature heat category although that part of it used to provide heat up to 100 C could in principle be supplied by sources of low-temperature heat. This represents a significant conservatism in a study since solar and other renewable methods of "pre-heating" are thereby precluded.

The balance between generalization and specification in the industrial sector was maintained by the fact that most provinces could in fact focus attention on just a few industries. Outside Ontario and Quebec, two or three industrial subsectors generally accounted for the bulk of energy use in a province: e.g. iron mining, pulp and paper and fishing in Newfoundland; forestry and smelting and refining in British Columbia; agriculture and other mining (potash) in Saskatchewan. In many instances interviews or plant visits could be arranged with officials in the key plants. In the absence of specific information, fall-back assumptions were used, as with the "other manufacturing" subsector of LTSM, efficiency gains for which were projected at the weighted average of efficiency gains among all the Task Force targets. In some cases, as with agriculture (which, as indicated above, is treated as an industrial subsector)[14] and

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[13] Energy balances in cogeneration were assumed, in the absence of other information, to be the same as those assumed by Statistics Canada in 57-003. That is, an energy input of 10 000 joules, is transformed into three outputs: 3 412 joules of electricity, 4 750 joules of steam and 1 838 joules of waste heat. The first-law efficiency of this process is defined as 3 412/ (3 412 + 1 838) or 65% compared with that of conventional thermal electricity, which is 3 412/10 000 or 34%. See further in Williams (1978) and Lalonde et al (1981).

[14] In many statistical compilations, Agriculture is buried in

Fishing, where the literature is particularly deficient, special investigations were carried out to identify more accurately the sources of energy use in 1978 and relationships between specific techniques and future savings.

A final special problem arises with the use, mainly in industry, of various forms of energy for non-energy purposes. The category includes greases, lubricating oils, heat transfer oils and a variety of other products, but these are small compared with the non-energy use of crude oil and natural gas to make petrochemicals and the use of coal to make coke (for use in metallurgy). As indicated above, non-energy use was disaggregated among the industries that used it; however, this was kept separate from direct energy use in those industries. Growth in non-energy use was then projected at the growth rate of the relevant industry with the assumption that the efficiency of use per unit output would increase by 5% in 2000 and 10% in 2025. The resulting non-energy use numbers for those years were then displayed in the energy supply tables in Chapter 3 (Tables CA-2 and CA-12 to CA-15). Non-Energy use thus does not show up in the demand tables in our study.

Transportation Sector

The transportation sector is relatively simple to handle in some respects and difficult in others. On the one hand, it is at present almost entirely fuelled by petroleum products; by far the major efficiency gains can be expected to come from improvement in the motive units themselves; and the demand for freight transportation is largely a result of industrial growth. On the other hand, the choice of fuels for the future is very wide; efficiency gains from system changes (eg. the substitution of telecommunications for for transportation, urban redesign to reduce commuting or industrial relocation to reduce freight charges) are very difficult to analyze; and a huge component of personal transportation is determined by lifestyle choices. For the most part, our study focussed on efficiency gains in, and fuels for, the vehicles themselves.

The Transportation sector can be divided into the following subsectors: automobiles and light trucks; heavy trucks; urban transit; intercity bus; rail; air; and marine. (For many purposes, and particularly for efficiency projections, an even finer classification must be used, as will be apparent below). The LTSM projected growth for each of these subsectors (except

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the Residential sector because of the difficulty of separating domestic use from farm use on individual farms. To the greatest extent possible, these two uses were separated in our study, at least in those provinces for which agriculture is an important industry.

the first), which, as indicated above, limited the extent to which modal shifts from one subsector to another could be considered to improve energy efficiency in transportation. In addition, the LTSM projected pipeline transportation, but for our purposes this sector was treated as part of the Energy Supply sector. Energy use in transportation in 1978 was obtained mainly from 57-003 but also from Statistics Canada Catalogue numbers 57-215 (Passenger Bus and Urban Transit Statistics), 53-218 (Road Motor Vehicles - Fuel Sales), 53-222 (Motor Carriers - Freight and Household Goods Movers) 52-210 (Railway Transport - Operating and Traffic Statistics), 54-002 (Shipping Statistics) and 51-001 (Transcontinental and Regional Air Carrier Operations) to make up for the fact that, as shown in Appendix 2.2, 57-003 breaks down road transportation differently from the way it is broken down in the LTSM.

Each of the major subsectors of transportation will be discussed in turn. For some, notably automobiles, there was an abundance of information, while for others very little information was available. To meet the needs of the study, special studies were carried out of energy use (and alternative fuels) in the rail, marine and air subsectors.

Automobiles and Light Trucks

Today, automobiles are the source of the bulk of energy used in transportation (about 55%), but with time they are expected to yield first place to commercial forms of transportation. This is largely a result of the huge gains in efficiency that can be expected--indeed, that are already visible--in automobiles and light trucks. The LTSM does not directly project an automobile sector, since it is considered a part of final demand; instead it was built separately assuming that the growth of the Canadian automobile fleet reaches an average of 1.1 vehicles per household from about 1.0 in 1978. (This figure of 1.1 is implicit in the level of industrial production, given the need to balance output and income and to keep international trade in balance.) However, this figure says nothing about the use of these vehicles nor about their efficiency. Given the rapid turnover of the vehicle fleet, and their inherently mobile character, it was logical to adopt some national standards for efficiency gains, while leaving determination of use patterns to each province.

Average automobile intensity in 1978 was 14.6 litres[15] per 100 kilometres (19.4 miles per gallon), but it is falling rapidly and is expected to be below 8.4 L/100 km (32.4 mpg) in 1985 (Motor Vehicles Manufacturers' Association, written communication, 1980). There are several European models now on the market with average fuel economies of around 5 L/100 km (57 mpg) and prototypes reaching 3 L/100 km (95 mpg) (Johansson et al, 1982). Based largely on the work of Ross and Williams (1981), Gray and von Hippel (1981), and Shackson and Leach (1982), all of which describe cost-effective ways to improve the efficiency of North American vehicles, the table below projects fleet intensity levels for new passenger cars and light trucks to the year 2000 and 2025 (with average fleet intensities, including older vehicles, in parentheses):

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[15] For conversion to other fuels, note that 1 litre of gasoline contains 34.65 MJ.

	INTENSITY (L/100 km)	
	Urban Vehicles	Non-Urban Vehicles
2000	4.8 (5.2)	6.4 (6.9)
2025	2.8 (3.2)	3.7 (4.3)

The distinction between urban and non-urban vehicles is critical. Not only can the urban vehicles be lighter, less powerful and hence more energy efficient, but each province was left free to utilize whatever fuel seemed most appropriate in that portion of its automobile/light truck fleet made up by urban vehicles. That is, based on the propositions that many vehicles operate entirely within an urban area (broadly defined; not just the urban core) and that a variety of automobile engines can be manufactured efficiently in an economy the size of Canada, there seems no reason to force a common fuel on regions with energy opportunities as different as, say, Halifax and Toronto. On the other hand, there was every reason to also have a different fleet, the non-urban vehicles, that were bigger, more powerful and had the capability of travelling everywhere in the country. The urban vehicles could therefore be fuelled by any one of a number of alternatives to conventional fuels including ethanol, methanol, electricity, synthetic gasoline or compressed natural gas; the alternative fuel for non-urban vehicles was, however, defined as methanol. (The rationale for, and interpretation of this choice will be discussed further in the supply section of this chapter.) By 2025, the number of automobiles is distributed by population as follows: for the urban population - 9 urban cars and 2 non-urban cars for every 10 households; for the rural population - 1 non-urban car for each household. This works out to just under the LTSM average of 1.1 vehicles per household in Canada.

The use of automobiles varies by province and by scenario. Starting from today's use, each province projected future use in the Business as Usual Scenario to maintain the number of kilometres driven per household constant. Given the reduction projected in persons per household, this implies a significant growth in per capita vehicle use. For the Consumer Saturation scenario, a reduction in use per household (from the level just specified) of up to 15% is permissible by the year 2000 and of up to 30% by the year 2025. However, this reduction in use is offset by the decrease in persons per household, resulting in per capita mobility only slightly less than in 1978. Most provincial analysts stayed well within these limits, and about half preferred the option of assuming no difference between the two scenarios.

Buses and Heavy Trucks

No system changes or load factor improvements were assumed for buses or heavy trucks, but substantial improvements in their specific efficiencies (energy use per seat-kilometre or per tonne-kilometre) were assumed compared with 1978. The gains in trucking, as with those in automobiles, are already in sight, and those for buses were derived by assuming that most of what could be done to increase energy efficiency with long-distance trucking could also be done with inter-city buses, but that opportunities were more limited with intra-city buses. In any event, the assumed reductions in intensity were as follows (Pacaud, 1979; Solar Energy Research Institute, 1981, p.311):

	Large Trucks	Inter-city Buses	Urban Buses
2000	35%	25%	15%
2025	50%	40%	30%

These savings are modest inasmuch as demonstration models of large trucks developed by Fruehauf have achieved 40% gains in efficiency through streamlining, use of aluminum and radial tires but no change in the engine (Krause, 1982). Both long-distance trucking and inter-city buses were assumed to shift gradually to a methanol fleet over time. Urban buses could operate on any of the range of fuels identified for urban passenger vehicles.

Rail Transportation

Efficiency improvements in rail transportation depend in part on the form of energy being used. We assumed that by the year 2000 the main line across Canada (Vancouver to Halifax) would be electrified but other lines would not be. Over time (after 2000) the branch lines would shift to using methanol from diesel fuel. At present, electric locomotives are about 77% and diesel locomotives about 27% efficient. Relative to electric locomotives in 1978, the intensity of electric locomotives is projected to be reduced by 21% by 2000 and 38% by 2025; relative to diesel locomotives in 1978, the intensity of methanol locomotives is projected to be reduced by 38% by 2000 and 47% by

2025. Both figures are based on a literature review conducted specially for the purposes of this study (see Appendix 2.3).

Air Transportation

As with rail transportation, a literature review was undertaken to develop a basis for projecting efficiency gains in air transportation (see also Schlichter, 1981), but in this instance the potential for using alternative fuels was also reviewed. The results are shown in the table below. The figures for intensity reductions are measured in seat-kilometres with intensity reductions for passenger-kilometres in parentheses; the latter include the effects of improved routing and higher load factors as well as improved air planes.

	FUEL		INTENSITY REDUCTIONS	
	Large Jets	Other Planes	Large Jets	Other Planes
2000	jet fuel	jet fuel gasoline	25%(40%)	25%(25%)
2025	liquid fuel (undetermined)	as above or methanol	35%(50%)	35%(35%)

The uncertainty in the type of fuel most appropriate for the large plane fleet in 2025 was left unresolved because it made little difference to our final results; the electricity sector (to produce liquid hydrogen), the biomass liquids sector (probably methanol) or remaining crude oil (refined to jet fuel) would each be big enough to supply requirements, but the choice would not affect the totals very much. In the Business as Usual scenario, air travel is assumed to increase by a factor of three; in the Consumer Saturation scenario the increase is left open for provincial adjustment, but in many cases the same increase as in the Business as Usual Scenario was assumed. No special adjustment was made in the air subsector (nor in the marine subsector) for the fact that many foreign carriers fuel up in Canada. Although this may distort results in a few spots (eg. Gander, Newfoundland), the effect of foreign purchases is generally balanced when Canadian carriers fuel up abroad. Furthermore, the difference between Canadian prices and world prices was not so great in 1978 (with Canadian prices about one-quarter lower in mid-year) to induce a large diversion of flights deliberately to buy fuel in Canada.

Marine Transportation

The choice of fuels and the projection of efficiency gains in marine transportation was also based on a literature review. Among other problems, a wide range of boats and ships are included in this subsector, including many fishing boats (which would more logically be classified in the Fishing industry, as most of the smaller ones probably are). It was found that what is called Marine Transportation has to be subdivided into at least three categories: (1) inshore fishing, pleasure boats, etc., (2) mid-shore and off-shore fishing, coastal freight, ferries etc.; and (3) large ocean-going vessels. Major gains in the first category will come simply from a shift to diesel, and in the latter two categories from a combination of factors including hull design, integration of systems (including on-board cogeneration) and propeller optimization. As with air transportation, the choice of fuels was not fixed partly because so many options exist and partly because the selection of one option or another does not make much difference in our final results. Even by 2025 it might be optimal to continue use of petroleum-based fuels for the two smaller categories, though methanol, vegetable oils or even methanol-to-hydrogen systems are all conceivable, at least for the medium-size range. The large, ocean-going vessels will likely return to steam generated from coal, coal-oil slurries or other bulk fuels from "the bottom of the barrel". Projected fleet average reductions in intensity per tonne-kilometre, relative to intensity in 1978, are as follows:

	VESSEL SIZE		
	Inshore	Mid-shore/coastal	Ocean going
2000	40%	25%	40%
2025	50%	40%	60%

Energy Supply Sector

In one sense the Energy Supply sector is an industry (or set of industries) just like any other in its search for improved efficiency, but in another sense it is that sector most directly affected by everything else happening in the study. For our purposes, the Energy Supply sector is defined by the following LTSM industries: Mineral Fuels, Petroleum Refining, Pipeline Transportation and the Electric Power, Gas and Other Utilities. Its energy use is defined by the 57-003 counterpart categories plus the energy losses associated with the production of electricity, coke and coke oven gas, which are not treated in the same way as the losses in production of petroleum products.

In effect, the energy intensity of the Energy Supply sector is determined by adding, source-by-source and form-by-form, the energy use for four stages of energy production: (1) primary production including mining, pumping or harvesting; (2) refining and processing; (3) transportation including pipelining, transmission and distribution of both sources and forms; and (4) thermodynamic losses in converting from one kind of energy to another (mainly primary sources to electricity). However, published statistics do not incorporate some categories, such as railroad and truck transportation of RPPs and gasoline service stations, within the appropriate energy supply industries but include them in other transportation and commercial categories.

In many cases, provincial analysts could find or calculate energy intensity factors specific to the energy supply subsectors in their respective provinces. In other cases general assumptions taken from Canadian averages for the energy efficiency of energy supply were employed either to simplify the analysis or to provide numbers for those provinces that could not find specific information. These energy-use factors, which are used in the creation of Tables CA-2 and CA-12 through CA-15, are as follows:

Crude Oil/RPPs

Pumping and Gathering of Crude:
    3% of the energy content of crude in the form of RPPs[16]
    0.2% of the energy content of crude in the form of electricity.
Refining (crude to RPPs):
    5% of the energy content of crude in the form of RPPs;
    0.7% of the energy content of crude in the form of natural gas;
    0.3% of the energy content of crude in the form of electricity.
Transportation and Distribution (Crude and RPPs):
    Neglected as either small or included in other categories.
Conversion of RPPs to Electricity:
    67% of the energy content of RPPs in the form of RPPs.

Natural Gas[17]

Pumping and Gathering and Processing:

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[16] 5% Offshore in Newfoundland

[17] All natural gas is measured statistically as marketable gas, which means post-processing.

0.2% of the energy content of gas in the form of RPPs;
4.0% of the energy content of the gas in the form of natural gas;
0.2% of the energy content of the gas in the form of electricity.

Transportation (Trunk lines across a province):
0.7% of system throughput per 1000 km of pipelining in the form of natural gas.[18]

Conversion to Electricity:
67% of the natural gas in the form of natural gas.

Coal and Peat[19]

Extraction and Primary Processing:
0.2% of energy content of the coal or peat in the form of RPPs;
0.2% of energy content of the coal or peat in the form of electricity.

Conversion to Electricity:
67% of the energy content of the coal in the form of coal.

Conversion to Coke and Coke Oven Gas:
9% of the energy content of the coal in the form of coal.

Transportation:
Data not available.

Electricity

Transmission and Distribution:
10% of electricity throughput or use in the form of electricity.

Biomass

Vegetable Oils Harvesting and Processing:

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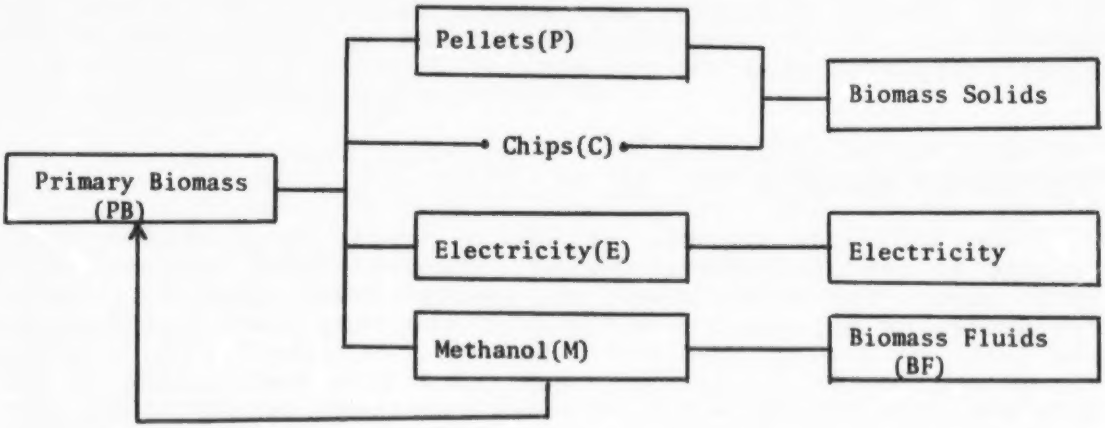
[18] For practical purposes this rule was modified to 0.7% of system throughout for each province except Ontario for which (because of the distance across) 1.4% was used. All pumping is assumed to be by natural gas.

[19] Preliminary data from Finland and Sweden indicate that for practical purposes peat can be treated as if it were coal. Energy used in drying is offset by lower extraction cost (Fagerlund and Ojefors, 1979).

10% of the energy content of the oils in the form of vegetable oil or RPPs.

The method used to calculate the Energy Supply sector requirements for the other forms of biomass-derived fuels was more complex since part of the fuel output was assumed to be used for biomass harvesting and since different amounts of different fuels could be produced from the original biomass. In order to calculate energy supply industry requirements the following model was used (as developed by Kirk Brown, the author of the PEI chapter in Volume II, based on empirical results in that province):



Energy Supply sector requirements could then be calculated using the following equation:

$$PB = (BS_P + BS_C + BS_E + \frac{BF}{0.65})(\frac{0.65}{0.65+0.10})$$

based upon the following conversion losses and fuel uses:

Wood Harvesting and Chipping:
    10% of the energy content of total harvested wood in the form of methanol or RPPs.
Conversion of Wood to Pellets:
    13% of the energy content of the wood in the form of wood;
    2% of the energy content of the wood in the form of electricity.
Conversion of Wood to Electricity:[20]
    73% of the energy content of the wood in

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[20] Based on a 20 MW plant.

the form of wood.

Conversion of Wood to Methanol:[21]

35% of the energy content of the wood in the form of wood;[22]

10% of the energy content of the wood in the form of electricity unless cogeneration is assumed.

Conversion of solid Biomass to Biogas:

50% of the energy content of the solid biomass in the form of biomass.

No conservation savings were assumed for the Energy Supply sector for conventional fuels. A very modest efficiency gain for methanol production was the only conservation saving assumed for the biomass industry, and modest conservation savings are embedded in the price reductions assumed for solar heating and electricity from wind and the sun.

2.5 SUPPLY ANALYSIS

Many specific aspects of energy supply have already been treated in the analysis of demand. It was almost impossible to talk about the quantities of energy being used in, say, residences or automobiles without at the same time referring to the forms of energy involved. However, it remains to describe the general method of analysis applied to the supply side of the soft energy analysis and to discuss some cost assumptions. The focus can remain entirely on the soft sources because in any year the supply of conventional fuels (essentially oil, natural gas and centrally generated electricity) is assumed to be infinitely elastic at the reference costs displayed in Table 2.4. Over time of course nonrenewable sources become depleted; these resource limitations are discussed in Section 3.4 below.

As an analysis of the potential for matching soft sources of energy to an efficient set of uses for that energy, a number of potentially large, but hard sources of energy for Canada were not included in our analysis. From the first, both new nuclear power plants (beyond those committed in 1978) and Arctic oil were excluded, and following the recommendations of the Parliamentary Special Committee, coal-based liquids were excluded (Canada, House of Commons, 1981, pp. 145-146). (Arctic sources of natural gas were not excluded from consideration but the results of the soft path analysis indicated no need to tap them.) The exclusion of nuclear power may seem to be inconsistent in that the infinitely elastic supply of electricity at reference costs is largely nuclear generated. The inconsistency is more apparent than real. The nuclear reference costs merely represent a cost barrier that soft sources must surmount in order to be considered cost-effective in a narrow (i.e., return on investment) sense. To the extent that this barrier is not surmounted, soft sources fail by that criterion and conventional alternatives (apart from those excluded from the beginning) would have to be called upon. Of course, soft sources might still be desirable on other grounds, and it is commonly asserted that they are. However, to be conservative, social, cultural, political and environmental aspects were, for the most part, put to one side in our analysis in order to look more carefully at the proximate economic and technical potential of soft energy supplies. Only if some environmental or social constraint was deemed to be of overwhelming and obvious importance was a specific source of conventional energy put to one side.

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[21] Based on a 1000 tonne per day plant.

[22] In 2025, declining from 40% at present.

No other conventional fuels were precluded in the soft path scenarios. Their use declined as their price rose beyond renewable forms of energy. Clearly, oil and natural gas are highly valuable sources of supply, and it would be silly to ignore their relative abundance in Canada and their role in a transition from non-renewable to renewable sources that is not expected to be complete even by 2025.

Because the reference costs rise with time, it is not necessary to be explicit at the start about the geographic or technical sources of supply. The natural gas might come from Sable Island and the oil from tar sands plants, or they might both come from wells in southern Alberta. Only in the final stage of analysis, when on a national level the total demand for energy must be compared with the availability of local soft sources, of more distant soft sources and of conventional non-renewable sources, does the question of specific source become a factor. As will be seen, the availability of these sources is at that time limited by a "reasonableness" criterion that affects both the choice and the rate of primary energy production. No region would be expected to produce from a source that was notably destructive of its natural environment nor to produce at a rate that was in excess of its own long-run interests, based on general resource management practices.

Analytic Method and Sources

The basic method for the analysis of supply involved the development of an inventory of renewable and nonrenewable energy sources and forms and the matching of those forms to the end-use quality categories derived from the demand analysis. In effect, the development of a supply inventory is the preliminary step necessary to create what would amount to an energy supply curve in each province or territory. Such a supply curve was not actually drawn because there were far too many variables, each with its own set of uncertainties, but it was the underlying concept. Production of nonrenewable energy sources and conventional hydroelectric sources were, as noted above, limited at reference cost levels only by outstanding environmental or social concerns and by keeping to a reasonable rate of development. The supply curve for renewable sources, however, was essentially built for this study from information on the costs of installing complete systems, as discussed in the subsections immediately below. As with nonrenewables, outstanding environmental and social concerns were taken into consideration as were any system effects (eg. peaking problems in back-up sources) and resource limitations (especially relevant for biomass). Careful attention was also paid to the rate at which any new system could replace an existing one, but because of the smaller scale of individual units there was less need for concern about an appropriate rate of development than with large-scale, centralized sources of nonrenewable energy.

Having developed an inventory of supplies that related availability to cost, it remained to introduce this information into the supply/demand patterns associated with the two scenarios. In the Business as Usual scenario the contribution of alternative sources of supply was determined mainly by comparative costs. Once a renewable source could be shown to be competitive with a nonrenewable one, it would start to make inroads into the markets at a rate based on the turnover of the capital stock (and, where applicable, retrofit investments) plus the time needed to prepare physical and institutional infrastructure. Although the reference costs for conventional sources and the costs developed in this study for renewable sources varied across the country, the possibilities for interprovincial trade and for the diffusion of technology keep such cost differentials fairly small. However, differences in penetration rates from province to province were to be expected. Even if marginal costs were identical, penetration of wind power would not likely occur at the same rate in, say, Prince Edward Island and Ontario. Both geographic and macro-economic conditions vary so widely that each province or territory was left to determine penetration rates for renewable sources on its own. The result was a changing supply mix in each region with a generally growing role for transitional technologies available within the province or territory. At this stage, some regions were left with a deficit (of some form of energy) and others with a surplus. Such deficits and surpluses were carried over to the stage of national integration.

Supply analysis for the Consumer Saturation scenario was not different from that for Business as Usual in any essential way except that, as any province or territory considered appropriate, softer sources could be introduced somewhat more rapidly than indicated by the rough measures of cost-effectiveness spelled out above. Decisions were based on the extent to which renewable sources were available and could be useful in meeting that region's energy needs in 2000 and 2025.

Costs of Soft and Renewable Sources

Information on the availability and economics of soft energy supply sources is often confusing. There is no dearth of information -- indeed, already there is almost too much -- but its quality is highly variable and commonly what one reads in one reference in contradicted by that in another. In many instances there are questions about applicability to Canada. In the end, we were forced to undertake our own literature reviews for a number of the renewable sources, including active solar space and water heating, methanol, photovoltaics and wind electricity (see Appendix 2.3). In addition, we relied heavily on the reports of EMR's Conservation and Renewable Energy Branch, (the predecessor to ECOSB), particularly with respect to biomass sources (Love, 1980 and 1981), on reports from agencies in other Governments, particularly those in Sweden, where soft alternatives are receiving considerable technical attention, and on the preparatory technical papers for the UN Conference on New and Renewable Sources of Energy that took place in Nairobi in 1981 (United Nations, 1980).

This section of the chapter will review the cost information on renewable sources in terms of the three main quality divisions: heat, electricity and liquids. As elsewhere, all costs are given in terms of 1980 dollars. Only the major systems are discussed here. Other systems of more local distribution, as with the use of municipal waste or of geothermal energy, are discussed as relevant in the provincial chapters (Volume II).

Soft Sources of Heat

A variety of soft, renewable sources of heating energy are available, particularly for the relatively large volume required at low temperatures for space and water heating. The main ones are solar, wood, peat and various forms of biogas. Though nonrenewable, peat is a good transition fuel and is included as a soft source.

Before the economics of these renewable sources of heating energy can be evaluated, it is necessary to estimate the system costs for conventional heating. Looking at a residence, the reference costs indicate only the cost to buy energy; to those costs must be added the costs for a system to get that energy into the home and to convert it into sensible heat. (This adjustment is overlooked in all too many energy studies; we want warmth, not energy.) The cost of a new, efficient gas furnace for a residence was taken as $2 000, and another $1 000 would be required for a pipeline connection to the main along the street.

(These costs are sufficient to preclude the use of natural gas in highly energy-efficient new homes with annual rates of use of less than 30 GJ per year, including cooking, but it may be justified for older homes whose annual energy use remains three or four times as high, even after retrofitting.) For electrical heating, the cost to retrofit a complete resistance heating system into an existing oil-heated home is estimated to be about $3 000, but a hybrid (plenum heater) oil-electric system designed to operate only during spring and fall could be installed for $1 000. The extra cost for electrical back-up for heating in new, energy-efficient homes is taken as zero; that is, the cost is no greater than what would be required for appliance and lighting use.

As noted above, a special problem arises for electrical utilities asked to provide back-up for heating systems that are largely independent because of low-energy design alone or low-energy design plus solar or wood systems. (Exactly the same problem arises with locally generated electricity, such as small wind and photovoltaic systems.) In principle, a central utility providing a lot of households with back-up heating could have substantial peak power requirements on a cold, stormy day in January but generate relatively little energy over the course of a year. A literature review undertaken for this study indicated that this problem need not be serious if systems are well designed, including provision for short-term storage at the consuming end and load management at both the consuming and the generating ends. In lieu of premium charges on consumers requiring only small amounts of back-up electricity, the analyst for each province or territory was left with the task of creating an electrical utility system that would be capable of bringing its average load factor to something in the range of 60 to 70%, as assumed in the reference cost study (Energy, Mines and Resources, Canada, Economic and Policy Analysis Sector, 1980). Some solutions will work and some will not. Because short-term storage of low-temperature heat is relatively cheap, the problem is one of seasonal peaks, not daily. Electric automobiles that can be charged during the night will not help, but industries that can generate their own power or shut down during winter peak periods will.

Turning now to renewable systems, consider first those based on wood. As with conventional systems, the cost for delivered energy is a compound of the cost to buy and deliver wood in some form and the cost of a system to burn the wood and distribute the heat around the house. Combustion devices cost between $2 and $5/GJ of delivered heat depending upon size and sophistication. (Small, hand-fed stoves cost the least; large, automatically fed furnaces cost the most.) Based on experience at the PEI Institute of Man and Resources, and allowing for conversion losses (about 25%), the total cost of wood excluding furnace costs is as follows: in the form of chips - $8/GJ; in the form of roundwood (logs) - $9/GJ; and in the form of pellets - $12/GJ. Incremental furnace costs will add between $2 to

$5/GJ, depending upon the system used. Real cost increases are expected to be roughly balanced by the technological gains in production and combustion. A somewhat different alternative involves the gasification of wood to produce a low-joule gas that can be used locally (ideally, on the farm where it is produced) for heat. Conversion losses are about 50%, but costs are so dependent upon local conditions that it is impossible to generalize.

Peat is comparable to wood in many respects and is attracting increasing attention as a local source of heat and, at central plants, of district heating and electricity (Fagerlund and Ojefors, 1979). It can also be converted to fluid fuel (Ettala and Asplund, 1979). Delivered to near-by sites, the cost of peat is about $2.50 to $3/GJ and, after drying, it can be used in homes in much the same way as wood. Supplies of peat in Canada are very large, but methods for long-term management and land reclamation are uncertain (Montreal Engineering, 1977).

Despite the fact that no technical barriers exist (Bezdek et al, 1982), only a small role was found for active solar heating, except toward the end of the period under consideration. Efficient buildings get most of their space heating energy from people, appliances and passive solar gain, and amortization of an active solar system to provide back-up is not now economically feasible. (The current high cost of seasonal storage is the main barrier. While major breakthroughs in this area are possible, they are not assumed here.) In contrast, there does appear to be a role for active solar water heating. Allowing for technical gains in collector efficiency and for economies as installation becomes more common, active solar water heating (with collectors operating from March to October) could become available for about $9/GJ in the next decade, and for about $16/GJ (with year-round collection) by the turn of the century. It is important to emphasize that these costs have not yet been realized, and that they depend upon the reduction of system cost-effectiveness to about $200 per annual gigajoule of capacity in 1990 and $150 by 2000. These goals are considered attainable by the National Research Council (Roger Peters, personal communication, 1982 -- based on costs and performance in the EMR Accelerated Demonstration Program; see also Bezdek et al, 1979) even though current costs are closer to $400 per annual gigajoule of capacity.[23] Domestic hot water systems are assumed to provide, as a rough Canadian average, about 15 GJ per year. In the most efficient new homes, this would be more than sufficient for all needs, but in older homes or those built to less than the most cost-effective standards, it would provide about 70% of hot water energy requirements. Solar system cost-effectiveness is, in fact, very sensitive to the cost of providing that additional 30% of hot water use. Commercial systems, being larger and typically having numerous sources of waste heat for back-up, should be less expensive than domestic.

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[23] One of the newer Canadian systems is expected to cost $1500 installed and to deliver four to seven gigajoules during its six months of operation per year. This implies costs of $215 to $375 per annual gigajoule of capacity or $20 to $35/GJ of heat (20 year life for the system and 7% real interest rate). (Roger Peters, personal communication, 1982).

The systems described to this point could be adapted, and probably used with greater efficiency, in industry to produce low-temperature process heat, steam or pre-heating (Bezdek et al, 1982; D. Strange, Renewable Energy Division, EMR, personal communication, 1982) but, as indicated above, the analysis of the last was precluded by data limitations. Where higher temperatures are required, more complex systems are available and beginning to find markets. Those most comparable to domestic solar systems use higher efficiency (eg, parabolic) collectors and/or maintain optimum collection efficiency by tracking the course of the sun as it moves over the day and year (Lovins, 1978, pp 492-4). Very different systems depending upon heliostats are not far from the competitive range (Caputo, 1981, pp 30-31). However, for the most part our study assumed that conventional sources, augmented by municipal wastes and biomass in some industries, would remain available and cost competitive for the production of high-temperature heat for the duration of the study period. High-temperature process heat accounts for only 10% of industrial energy use, and it can be saved more cheaply by, say, recycling than produced by high-tech solar systems.

Soft Sources of Electricity

The share of energy use required in the form of electricity in this study is twice or three times what it is in most soft energy studies. This is a result of an explicit choice to violate strict thermodynamic matching of energy sources to uses by quality and to permit certain demands for heat to be provided by electricity. The choice reflects the general energy situation in Canada, but it does mean that our results are not directly comparable with those of other soft energy studies and it does add to the burden of finding cost-effective and environmentally acceptable sources of electricity.

The major opportunities for renewable electricity other than hydro-electricity come from the combustion of renewable fuels and from wind machines and photovoltaics. Cogeneration of electricity is treated with conservation because, as noted above, the industrial Task Force targets represent savings of purchased energy, which implies that they already include cogeneration. In combustion, either peat or wood can be used to fuel thermal electric plants at costs that are competitive with oil-fired generating stations today. They appear to be more attractive in smaller scale plants (20 to 120 MW), particularly if a use can be found for the waste heat, which is about 25% greater than with fossil fuel-fired plants (ADI Ltd., 1979). However, major use of these fuels for electrical generation does not seem likely.

Costs for wind and photovoltaic systems were each developed in special literature reviews, which found that these sources are not competitive today (except in special locations) but that modest technical gains, which are already being realized, and longer production runs would make them attractive. As with active solar water heating, system costs are highly sensitive to the costs for back-up electricity. Photovoltaics will first be attractive where use can also be found for the large amounts of waste heat they give off, which suggests industrial and commercial rather than residential use. The literature reviews also suggested that system problems can arise if too large a proportion of generating capacity is based on these systems, which could all become inoperative at the same time. For the purposes of this study, no more than 15% of any system capacity could be based on either wind or photovoltaic systems, and no more than 20% of the two taken together (see also Diesendorf, 1981).

With respect to wind, the technical papers prepared as background documents for the UN Conference on New and Renewable Forms of Energy developed estimates of "ultimate installed costs" on the basis of the 100th to 1000th unit installed. Thus, while wind energy is currently about twice as expensive (under most conditions) as conventional, its ultimate cost is well within the range at which it would be cost competitive (United Nations, 1980). The projected cost for machines larger than about 200 kW is expected to reach $1100/kW (peak) by the end of the 1980s; on the same basis smaller machines would reach $725/kW (peak). Our literature review went on to demonstrate that, depending upon load factors, at penetration levels of 14 to 20% in grids, the cost of wind-generated electricity comes to $0.044 to $0.062 per kW.h after adjusting for land, operation and maintenance costs (see also ESL Environmental Sciences Ltd. and the IBI Group, 1981).

No comparable cost figures could be projected for photovoltaic devices because the technology is so dynamic. Certainly the capital cost target of the U.S. Department of Energy of $500/kW (peak) seems likely to be realized, but this is inadequate to tell much about average costs. However, the greater questions seem to involve the nature of the systems in which the devices would be used. Evidently, in the absence of buy-back provisions, small-scale arrays, such as seem appropriate for homes, would not be viable unless they could supply essentially all requirements. This suggests that one option may involve utility ownership in which the photovoltaics are optimally linked with back-up generation. Unfortunately, no one has studied this question for Canadian winter peaking utilities nor has anyone considered integration with wind systems (which on an annual balance are almost perfectly complementary with solar). All of this left soft energy researchers with little hard information but many degrees of freedom for dealing with photovoltaic cells, subject to the overall constraint indicated above.

Soft Sources of Liquid Fuel

Finding ways of producing liquid fuel has always been the most difficult part of energy analysis, whether soft or hard. Our study focussed mainly on methanol which has received most attention in Canada because it can be readily produced from wood; indeed, it is called wood alcohol. (Today, the major feedstock from which methanol is produced is natural gas; coal could also become a major feedstock.) However, our focus is not intended to reflect a final choice for methanol, the simplest alcohol, but rather an analytic convenience. There are advantages and disadvantages in going to the higher alcohols, particularly ethanol, which can also, under a somewhat more complex process, be made from wood (Stone and Marshall, 1980) or alternatively using methanol as a source of hydrogen with "on-board" conversion (McCormick and Huff, 1980). While the word methanol should therefore be read as if it were contained within quotation marks, there is reason to think that it is in fact the best choice for Canada. Certainly hydrogen systems are speculative at best (Ontario Hydrogen Energy Task Force, 1981, Volume 5); moreover a comparative analysis of methanol and ethanol production processes that was undertaken for this study shows that the former yields almost twice as much energy as the latter per unit of biomass feedstock. (Because individual estimates of methanol and ethanol production potentials have been so much at variance, this comparative analysis is attached as Appendix 2.5.) As a further effort at neutrality, comparison of methanol with gasoline is made on a joule-for-joule basis. This is a significant conservatism inasmuch as alcohols contain less energy per litre than gasoline but engines specifically designed for their use (especially stratified charge engines) get almost equal efficiency per litre (Connerty, 1979), which implies up to a 40% gain per joule.

The essence of our studies is that methanol could, by the year 2000, be produced from a wood feedstock in 1000 tonne-per-day (methanol output) plants for between $7 and $8.59/GJ. (Current costs are $11.00 to $14.00/GJ (R.Overend, National Research Council, personal communication, 1982.) This is compatible with projections from a recent study done for the B.C. government which suggests that a 1,000 tonne-per-day wood-based methanol plant in the B.C interior could produce methanol at $7.74/GJ (Canadian Resourcecon, 1981). This figure is based on the availability of wood (initially wood waste) at $22 per tonne and a conversion rate of 2.6 tonnes of wood to one of methanol. We assume further that 10 to 15 oven-dried tonnes (ODt) can be produced per hectare of land on a sustained yield basis using short (5 to 8 year) rotations and a variety of clones. This figure drops to about 2.5 ODt per hectare in northern parts of the prairie provinces. Intensive management (including fertilization) could double these yields (R. Overend, National Research Council, personal communication, 1982). Allowing for rising real costs of production, the following escalation is typical, using Alberta as the example:

	Wood($/ODt)	Methanol ($/GJ)
1978	10	7
1990	30	9
2000	50	12
2025	50	12

Costs for wood or peat are somewhat higher in eastern Canada and thus so are methanol costs. However, more rapid rotations could equalize costs. Conversion efficiency is expected to climb slowly toward 65% (including allowance for collection).

As it turns out, at the costs suggested above, the main limitation on methanol use is less processing cost than the availability of biomass feedstock (see also Appendix 2.5). The major sources, assuming that mill wastes are largely used for fuel in the forest and paper industries, are forest residues, tree plantations and culling of trees being grown for pulp or timber. However, total costs and yields are both qualified by uncertain land-use impacts and the environmental effects of rapid and complete harvesting (Beale and Heeney, 1981). One way to reduce both costs and environmental impacts during the first part of the period under consideration would be to use natural gas as the processing fuel (rather than drawing that fuel off the biomass feedstock). Capital costs are only about one-half as large and much less sensitive to plant size.

Although methanol can be used to fuel diesel as well as gasoline vehicles, a better alternative to diesel fuel appears to lie with vegetable oils (Erickson and Dixon, 1980; Hall, 1981; Jensen Engineering, 1981, p.56). Some vegetable oils, including canola (rapeseed oil), which is produced in large quantities on the Prairies, contain almost 40 GJ per tonne and are an almost perfect substitute for diesel oil. They can in fact be used directly, though refining to reduce the carbon content prolongs engine life at little additional energy cost. Overall, about 10% of the energy content must be used for harvesting and processing. At present canola is more valuable as an edible oil than as fuel, and it does not appear that a crossover will come much before the year 2000. However, several considerations could bring that crossover point closer in time, at least for on-farm use (which accounts for nearly half of diesel use in Saskatchewan). A large amount of land is currently left in summer fallow, which is generally agreed to be a poor farming practice (Jensen Engineering, 1981), so the opportunity cost of using that land to produce a fuel crop would actually be negative. Moreover, canola has been selectively bred to improve flavour and reduce poisons; varieties exist with more oil than those typical of today's crops.

In no other area of renewable energy alteration can such divergent views about technical factors be found as when dealing with biomass conversions to liquid fuels (see, for example, Pimental, 1981). We hear both that producing ethanol from wood is not worth considering and that it is (using acid hydrolysis) a proven technology; we find reported figures for potential biomass harvest on a sustained yield basis varying by factors of four; and we find reports of the energy efficiency of various processing techniques that vary by factors of three or more. Some of the differences can be attributed to failure to specify precisely the steps or the materials or the processes under study. However, this appears to be an area where the lack of actual operating experience (except for conventional alcohol production) precludes the development of better figures at this time. Ironically, it impinges on that energy quality category, Liquid Fuel, that is the most critical for future supply considerations.

2.6 INTEGRATION OF STUDY COMPONENTS

Several parts of the soft energy path study had to be integrated at appropriate stages in the course of completing the work. This section will discuss briefly how that integration was accomplished at three stages: (1) within each province, (2) among provinces so as to create a national energy economy, and (3) from one year to the next.

Provincial Supply and Demand

Each province and territory had to integrate the demand and supply components of its energy economy for the years 2000 and 2025. Essentially, this was accomplished by starting with the sets of end-use demand projections, as developed for each of the two years and each of the two scenarios under study, and comparing those projections with the availability and cost of various soft forms of supply. In principle, a demand curve for each quality of energy was compared with a supply curve of that quality of energy, but the actual analysis was more a matter of mixing and matching to get the best fit. In most cases this meant determining whether the supplies of renewable forms of energy were large enough and cheap enough to provide reasonably for the projected levels of energy use, and, if they were not, identifying the availability of conventional fuels or transitional technologies from within the same province or territory to fill the gap. In some cases, there were still remaining surpluses or deficits and these had to be dealt with in the next stage, viz, inter-regional integration.

No specific method was imposed for matching supply and demand within any province or territory. Going beyond general rules at this stage typically defeats the purpose of soft energy studies because it tends to force "top down" solutions and to ignore the potential for "bottom up" ones. However, it was clear that even by 2000 and certainly by 2025 there should be no need to look outside any region, indeed outside any structure, for heating and cooling energy. The key gap at the level of the province or territory most often turned out to be liquid fuel for transportation. Even this gap could likely have been reduced further had there been more opportunity to try more runs of the LTSM or more time to investigate ways to improve the efficiency of the transportation system (as opposed to simply the efficiency of the motive units themselves). Similarly, some of the remaining gaps in industrial energy might have been reduced by making goods more durable or more easily recyclable.

To some extent, of course, such variations (along with many simpler ones) were reviewed at the regional level. It is a general conclusion of soft path analysis that supply/demand gaps can generally be filled more easily from the demand side than from the supply side. To the extent that time permits, analysts make iterations from demand to supply and then back around again. In particular, having identified a gap in the capability for soft sources to provide for secondary demand, they re-analyze those demand "requirements" to see whether or not there are cost-effective ways to cut them still further (while continuing to provide the same level of final end-use services). If there are, this creates a new supply/demand balance. Such reiterations are typically buried in the provincial and territorial analyses, for each balance is considered only an interim working result until time limitations force an end to the process.

It was at this stage of the analysis that it became critical to determine the appropriate rate and type of conventional energy production in any province or territory. As indicated above, a number of energy sources were excluded as being too hard for consideration. In the case of coal liquids and Arctic oil, this meant simply that no production at all was considered as available; in the case of nuclear power stations, which of course already exist, it meant no additional stations beyond those under construction in 1978 and the gradual retirement of all nuclear stations at the end of their normal working life (assumed to be 40 years). In addition, each region could exclude from consideration specific sources of primary supply that were deemed to be too environmentally destructive, even if the energy might have been used internally and especially if it would have been exported to other regions. As it turned out, there were relatively few such exclusions, but those that did arise, as with the potential for hydroelectric dams on the Stikine River in British Columbia or on the Churchill River in Saskatchevan, were not considered further. Similarly, many provinces did not accept that some identified sources of biomass, such as straw, should be used for energy and assumed instead that all was returned to the soil.

The issues involved in primary production extend beyond the choice of sites to the scale of investment in conventional sources, which in turn determines the rate of primary production. Given the physical availability of resources, the question is how rapidly (or at what scale) they should be developed. For example, how rapidly should Alberta deplete its crude oil reserves, and how extensively should Labrador develop its hydroelectric capacity? For the most part, the question is critical only for those "energy surplus" regions with significant capability of exporting to "deficit" regions. On the one hand, investment could be slow to maintain internal supplies (of a depletable resource) as long as possible or to reduce impacts within that region; on the other hand, energy is a valuable commodity in trade and it is unlikely to be hoarded if it can be sold profitably. The general guideline here is an economic one: each region should develop capacity to the degree that will maximize its own long-run benefits. No specific rules were set for determining those benefits; in effect, each province or territory was left with the need to set a level of investment in the energy supply industry that was "reasonable" given its own political and economic situation.

The final steps in the intra-regional integration involved building up the Energy Supply sector and adding in non-energy uses. Using the efficiency factors specified above, this was a matter of fairly straightforward calculation in the first instance to determine the volumes of both primary sources and secondary forms that would be needed to produce and deliver the required volume of end-use energy. However, in detail, the calculations could be complex. Among other problems, provinces with a potential surplus had to wait to complete their Energy Supply sector until export requirements were estimated, and provinces across which energy was transported had to await the final determination of those volumes (in the inter-regional balancing step), before completing theirs.

National Integration

There were essentially two tasks in the integration of the provincial and territorial soft energy studies to obtain national results. The first involved the summing of the various supply and demand components to obtain national totals. Little needs be said about this process, which was conceptually simple though more than the usual number of difficulties appeared in practice. The tables that appear in Chapter 3 of this volume were derived by this process.

The second task in national integration involved the need to deal with energy surplus regions and energy deficit regions. The method adopted to create a national balance was carefully controlled. Each province and territory was required to produce a working table based on the intra-regional analysis described just above that provided a preliminary indication of its surplus or deficit of energy by year, by scenario and by form. (In practice, the table only had to be completed for the six types of energy capable of being transported or transmitted any distance: crude oil, RPPs, natural gas, coal and peat, biomass fluids and electricity.) In effect, an equation was defined for each province and territory which stated that the primary production required of any energy source was equal to the secondary use of the energy forms derived from that source plus the associated requirements of the Energy Supply industry plus Non-Energy use. As it turned out, the primary production required might be greater or less than that available, which in turn defined the extent of surplus or deficit.

The first set of working tables permitted the construction, at the national level, of a second working table in the form of a matrix with each province/territory appearing on both axes. The rows showed where energy was needed, and the columns showed where it could be obtained. The diagonal cells (eg., where the Manitoba row intersected the Manitoba column) were filled to the extent possible with self-produced supplies. Such a matrix had to be completed for each major form of energy for each scenario in each of the two years of analysis.

It was of course largely a matter of judgement how to fill in the non-diagonal cells of the matrix. The surpluses and deficits were known from the working tables but there was no formal way of transferring surplus production from a surplus province to meet the deficit in another. Essentially our method consisted of gathering the provincial researchers around a table and filling deficits in ways that made intuitive sense, mainly in terms of minimizing transportation costs and maintaining existing linkages. Thus, Nova Scotia coal was used to fill Quebec's demand for industrial process heat, but Ontario's demand for metallurgical coal was assumed to be imported from the United States.

The method of roundtable allocation also permitted us to deal simultaneously with the problem of energy supply requirements. Once it was determined, for example, that Alberta would send a certain volume of natural gas to Manitoba, the Alberta analyst could determine the energy supply requirements to produce that gas and move it to the border, and the Saskatchewan analyst could determine the volume necessary to pump the gas across that province.[24] The same process was followed for each form until almost all Canadian requirements were met from Canadian sources. A few imports of special products continued, and there were substantial national surpluses of electricity and of natural gas remaining.

Integration Over Time

Integration of the provincial/territorial and the national results over time was the final stage of the soft path analysis. To some degree this longitudinal integration is accomplished by the study method itself. The LTSM projections provide an integration framework on the demand side, and the reference prices for conventional forms of energy (which limit the rate at which new and less economic energy sources can be introduced) does the same for the supply side. In a mechanical sense, little more needs be said.

However, implementation schemes and energy policy are of course the targets at which soft path studies are really aimed. It was necessary to show that the results at both national and provincial/territorial levels were in fact achievable over the 47-year time period. The questions are: Can we get there from here? If so, by what routes? What are their advantages and disadvantages, social costs and environmental impacts? And will political forces permit us to take this route? Clearly, following through on such questions, important as they may be, represents another study of the scale of this one -- another study that, one must add, would likely be more complex in analysis and less certain in results, than this one.

In lieu of undertaking a full analysis of implementation, this study agreed to a more limited goal. The final stage would be an indicative analysis to show that there was indeed a route from here to there, that there were no insurmountable blocks on that route and that it was reasonably attractive from the political and social points of view. No claim is made that the route presented is the only route open and certainly not that it is the best one. Only that it does exist, and that it is feasible.

To be more specific, the method adopted was to look at the soft path results for each province or territory under each of the two scenarios and indicate what policy measures would be sufficient and acceptable to achieve those results in 2000 and 2025. Further, some indication had to be provided of the sorts of implementation schemes that would be needed to back up those policies. Finally, a rough assessment was made of some of the impacts of the energy scenarios and the economic projections on both economic variables and the environment. Neither was investigated in any depth. Economic variables, such as labour productivity, were derived in a straightforward way from LTSM. Environmental impacts were based on general knowledge of the natural systems and changing technology of production and use. Where apparent, social impacts were also identified. No attempt was made to be quantitative in any of these assessments except where calculations could be obtained directly from other parts of the study.

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[24] This process is yet more complex as those additional energy supply requirements must themselves be produced and transported. An infinite chain of effects is created, but the size of those effects diminishes rapidly after a single round.

CHAPTER 3: RESULTS

This chapter will present the principal results of our projections. The work described here has two sources: (1) the methods for projecting the Canadian economy by sectors and by provinces, and for adjusting those results to reflect increased energy productivity, as described in Chapter 2 of this volume; and (2) the results from the twelve provincial and territorial analyses, as presented in Volume II of our report, the algebraic sum of which to a great extent yields the national results described here. This chapter is divided into six sections: the current situation, the future economy, energy use in 2000 and 2025, energy sources in 2000 and 2025, energy balances in 2000 and 2025, and energy flows. Thus, the organization within this one chapter of Volume 1 follows closely that within each provincial chapter of Volume II. And, as noted elsewhere, the major tables and figures correspond, so that Figure CA-3 here, for example, shows for Canada just what Figure AB-3 shows for Alberta. These standard tables and figures are all contained at the end of this chapter. Additional tables and figures, which are scattered throughout the chapter, are numbered separately.

Emphasis in this chapter is on the quantitative results for Canada as a whole, though some attention is paid to provincial variations around national results. Discussion of implications and impacts is, for the most part, deferred to the next chapter. The major results of the study insofar as demand is concerned appear in five tables: Table CA-1 (for 1978) and Tables CA-8 through CA-11 (for 2000 and 2025 under each of the two scenarios). The major results for supply appear in five comparable tables: Numbers CA-2 and CA-12 through CA-15. As in the provincial reports, summary tables are also provided showing changes in key economic and demographic variables (CA-3) and in sectoral use (CA-4 to CA-7). Demand and supply are brought together schematically in eight figures: numbers CA-1 through CA-8. These fifteen summary tables and eight summary figures can be found at the end of the chapter. Appendix 3.1 provides general notes for the reading of these tables and figures.

3.1 THE CURRENT SITUATION

Canada is a large country with a large economy and, in part as a result, a large energy appetite. The population of 24 million is found mainly in a strip 300 km wide (south to north) and 7 000 km long (east to west). Not only does this strip include maritime, continental and mountain conditions, but smaller population clusters are found further north. Despite the northern location -- heating seasons of 6 000 degree-days are not uncommon -- much of this population has adopted the single-family-home/commute-to-work-by-auto lifestyle of the United States, just to the South. The adoption of southern lifestyle in a northern country is possible because Canada is among the richer countries in the world in terms of per capita income. However, relative to most other western nations, the economic activity which supports that income is highly concentrated in the primary sectors based on mineral extraction, forestry, agriculture and fishing. These factors, together with the enormous economic and demographic diversity across the nation, explain a great deal about Canada's energy economy, to which we now turn.

The general pattern of existing sources and uses of energy in Canada is fairly well understood from a macro perspective. Tables CA-1 and CA-2 and Figure CA-1 show the disposition of energy by primary source and secondary form, by end-use sector and by quality category for 1978.

The tables and figures show that 5990 PJ of energy (6540 PJ if one includes non-energy products as well), or 75% to 80% as much energy as is produced in Canada, reaches the consumer and is used as a secondary energy product. This represents 256 GJ per person, giving Canada among the highest per capita energy use of any major country in the world. Per unit of GNP, we use 23.4 MJ per dollar, a figure which places Canada first among industrial countries according to some analyses (Darmstadter *et al*, 1977) or about the middle of the range according to others (Energy, Mines and Resources, Canada, Economic Analysis Division, 1981).

The largest end-use quality category is Liquid Fuel (almost exactly one-third of total secondary use) representing mainly the portable fuels needed for transportation. This end-use is all but entirely satisfied with refined petroleum products (RPPs). Slightly over half of the RPPs is used in transportation. The other half is used for heating and cooling or to provide process heat for industry, but such uses do not generally *require* liquid fuels.

Close behind the Liquid Fuel quality category is Heating and Cooling (30% of the total), representing mainly space and water heating but also industrial process heat below 100°C. Intermediate-Temperature Process Heat (100° to 260° C) takes less than half as much secondary energy as Heating and Cooling (13%), and High-Temperature Process Heat (above 260° C) takes a little less (11%). As in every other economy, then, energy for heating in Canada dominates the statistics--54% of total secondary energy use. However, the proportion of High-Temperature Process Heat is uncommon and reflects Canada's specialization in primary products. The bulk of heating needs are provided by RPPs and natural gas, but electricity, coal and wood also provide a significant share (the first mainly for residences; the latter two mainly for industry).

With 12% of use, the Electricity Specific category is the second smallest (after High-Temperature Process Heat) of the quality groups. In principle, this category includes only those uses which require electricity. For the purposes of this report, data gaps led to a looser definition: Electricity Specific means all current electricity uses except space and water heating and cooling. (Many other studies identify only 7 or 8% of secondary energy use as Electricity Specific; this difference represents a conservatism in this study.) Electricity Specific uses as defined here account for three-quarters of actual electricity use. The sources of electricity were, in decreasing order, hydro, fossil fuel (coal, oil and natural gas), nuclear and biomass.

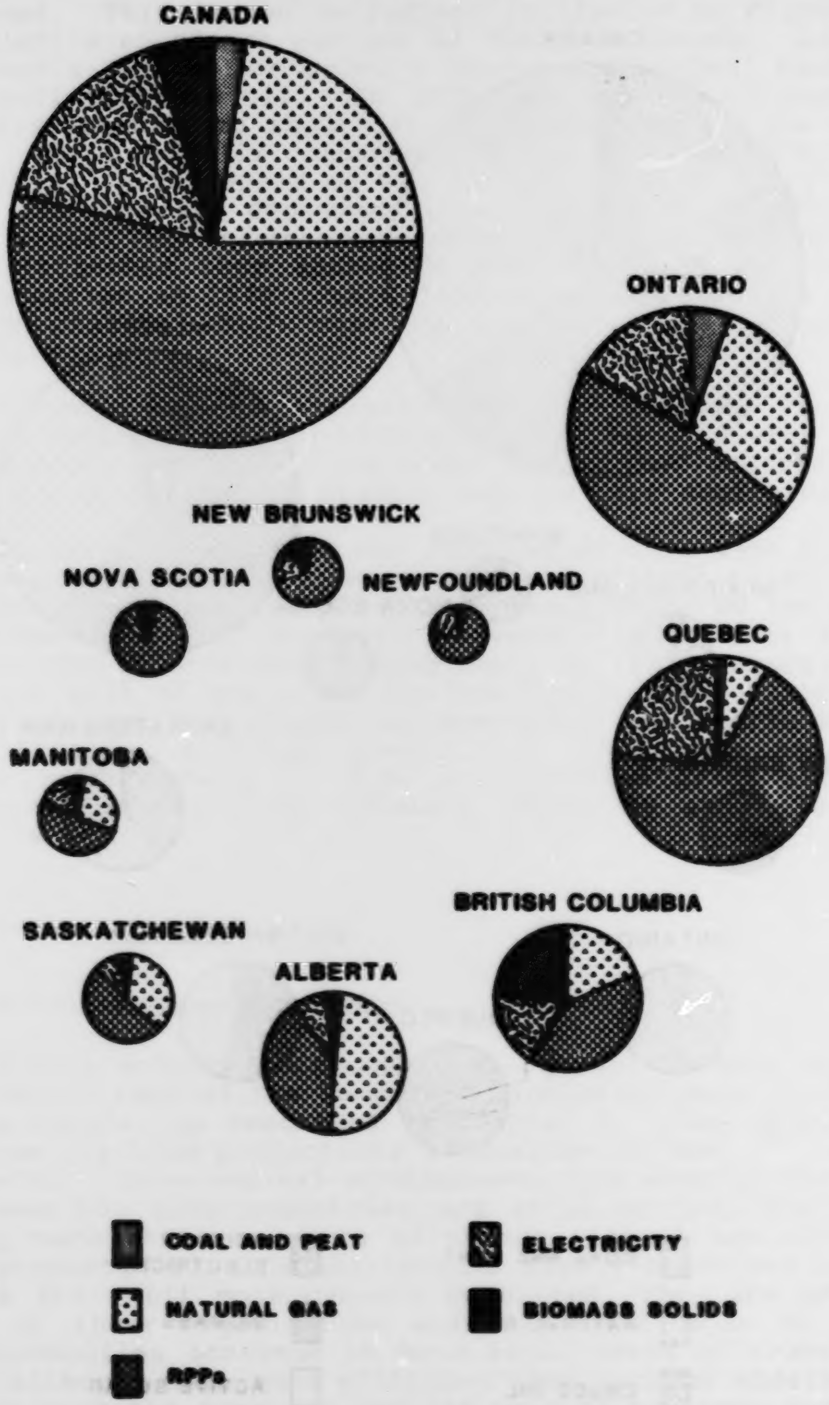
In terms of sectors, industry consumes the most energy, followed closely by transportation. While the former sector uses a mix of fuels, including virtually all of the coal and coal products consumed in Canada (mainly to provide process heat and as coke to serve as a reductant), transportation is all but totally dependent upon oil products. (The small amount of urban electrical transportation barely shows.) Between them, the Residential and Commercial sectors account for about one-third of total energy use, mainly for heating and cooling and most of this is oil products, natural gas or electricity.

Canada is currently self-sufficient in terms of overall energy production and use. In 1978, just under 8200 PJ of primary energy was produced in the country. Total exports of just under 1000 PJ exceeded total imports (mainly crude oil and oil products) by about 400 PJ, resulting in a positive energy trade balance.

Aggregate figures of course tell only a part of the story. Looking more closely at the Canadian energy situation, it becomes clear that certain factors are of considerable importance. In particular, Canada's positive overall energy balance is offset by substantial differences among the provinces in terms of the energy they produce and the energy they use. Figures 3.1 and 3.2 show primary energy production and secondary energy use in Canada by province in 1978. The two figures reveal a good deal about the political economy of energy in Canada. It can be seen that, while Alberta produces by far the most energy, Ontario and Quebec use the most. Moreover, there are significant regional concentrations of production by source while use is much more evenly distributed (per capita use is almost uniform across the country). Equally great differences are shown for the distribution of energy among sectors. Nationally industry takes 37% of total secondary energy, but within provinces the share ranges from less than 9% (Prince Edward Island) to more than 50% (British Columbia). With Ontario and Quebec between them accounting for 60% of Canadian energy use, it is easy to miss the wide variations that occur in the eight provinces and two territories that account for the remaining 40% of use.

FIGURE 3.1

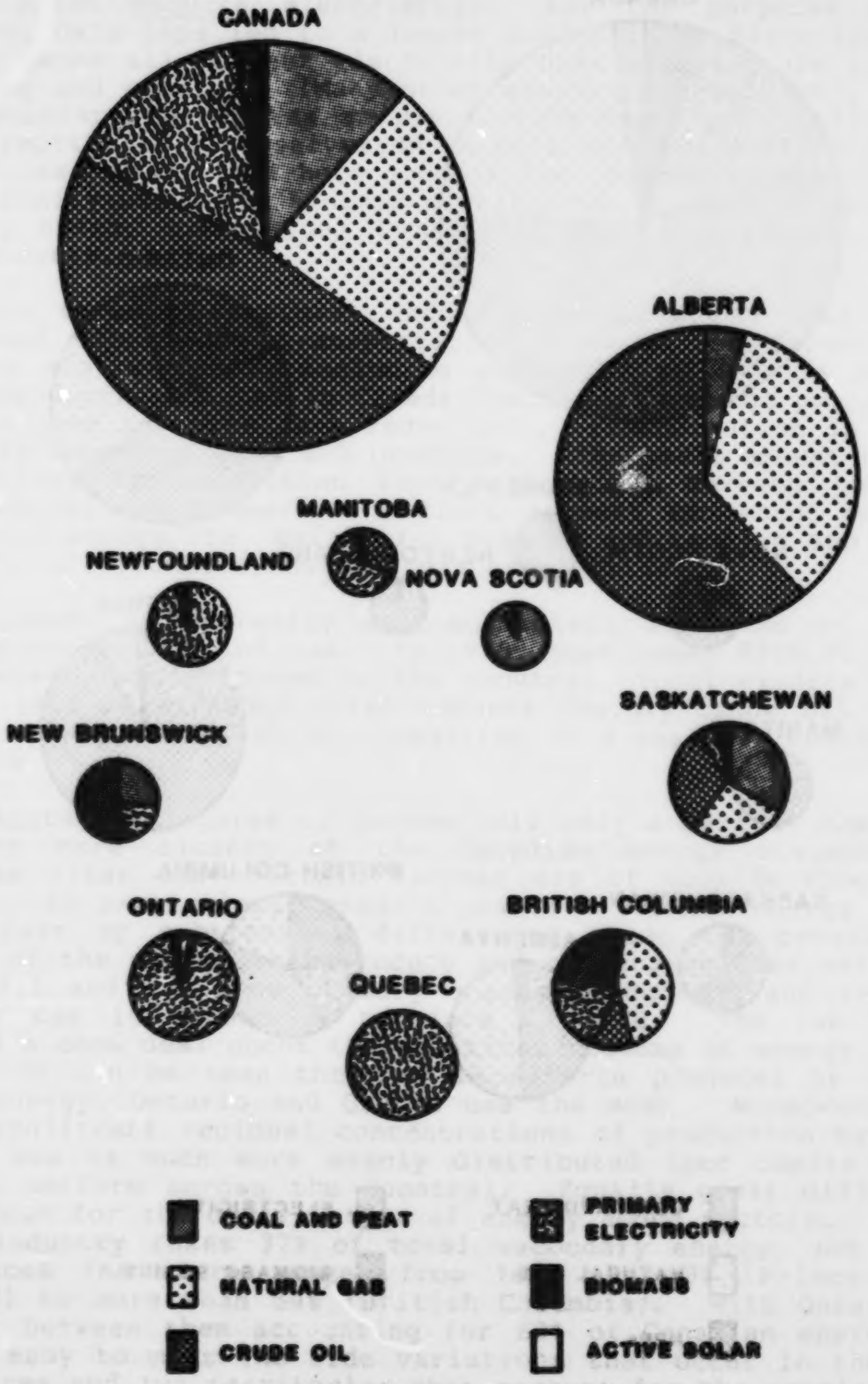
PROVINCIAL DISTRIBUTION OF SECONDARY ENERGY USE IN CANADA IN 1978



NOTE: P.E.I. AND THE TERRITORIES ARE LESS THAN ONE PERCENT OF THE CANADIAN TOTAL

FIGURE 3.2

PROVINCIAL DISTRIBUTION OF PRIMARY ENERGY PRODUCTION FOR USE IN CANADA IN 1978



NOTE: P.E.I. AND THE TERRITORIES ARE LESS THAN ONE PERCENT OF THE CANADIAN TOTAL

The lesson of Figures 3.2 and 3.3 is that the energy problem in Canada has a lot to do with regional disparities and with the transportation of energy from energy-rich provinces to energy-poor ones. This lesson is further reinforced by disparities in the relative abundance and use of fuels in Canada. Although oil represents 42% of our primary energy production, Canada is not self-sufficient in oil. In 1978, net imports of crude oil and products amounted to about 22% of total secondary use of oil products. The problem is compounded by the fact that the Atlantic provinces, which depend on oil for over 80% of total secondary use, are entirely dependent upon imported oil. When combined with the lack of energy resources indigenous to these provinces (together they accounted for only 3.5% of Canadian energy production in 1978), this dependence represents a critical policy problem which must be addressed by any proposed energy strategy.

In contrast to the situation for oil, Canada is a net exporter of natural gas. In 1978 nearly 850 PJ of energy in the form of natural gas (about one-third of total production) was exported, all to the United States; imports were negligible.

Canada was also a modest net exporter of coal with over 500 PJ being exported (mainly from Alberta and British Columbia and destined for Japan) and 480 petajoules being imported (mainly to Ontario from the United States). However, all of the exports and much of the imports were coking coal; so far as energy products go, the bulk of the trade was the importation of about 270 petajoules of coal for electrical generation in Ontario Hydro's plants. Finally, although electricity flows back and forth across the border where the U.S. and Canadian grids interconnect, the net trade is in Canada's favour by about 76 petajoules.

3.2 THE FUTURE ECONOMY OF CANADA

The future economy that underlies our soft energy analysis is projected in runs of the Long-Term Simulation Model (LTSM) of Statistics Canada, as described in Chapter 2. The Canada that results from the LTSM projections is similar to that of today in most respects. Governmental arrangements are exactly the same, more or less the same industries are still active, and people are buying much the same sorts of things (though not always in the same proportions). Canada remains highly urbanized and, if the cities are a bit more densely populated, they are not much different in their organization and form from those of today. Private automobiles continue to be a major means of transportation and, although much more efficient than current models, they are used in much the same way and for most of the same purposes.

Similarly, other consumer durables are more efficient in providing services, but they are not used in more efficient ways nor are they any more durable or more easily repaired or recycled than those of today. These conservatisms are not insignificant. A variety of minor changes in the use of hot water in residences (e.g., cold water clothes washes) can save up to 25% of the energy used to heat water (Middleton Associates, 1981), and average automobile life could be doubled for an increase cost of about 30% (Porsche Development Center; cited in Ross and Williams, 1981). The lack of such features in this study does not of course imply opposition to greater durability or recycling but merely indicates that, even in their absence, a soft energy future is feasible in Canada.

In effect, the LTSM creates "surprise-free" projections that: (a) continue today's trends toward lower population growth and smaller households, and that (b) allow for two variations in economic growth, one in which people work more hours per year and have greater expenditures and another in which they work fewer hours and have lower expenditures. The following couple of pages describe the one population projection and the two economic projections (for more detail, see McInnis and Trepanier, 1979), which combine to create the two scenarios used in this study. Table CA-3 provides the quantitative results of projection under the two scenarios, and Figure CA-3 shows the relationships among the key variables. From the latter it is clear that energy growth falls well below population and economic growth, and one can infer that it would require substantial increases in those variables to pull energy growth much above zero.

Population

In the projections, the birth rate in Canada falls to the replacement level by the early 1990s, but population continues to rise, though at a declining rate, because of continued net immigration of 100 000 per year. The overall rate of population growth is 1.0% per year (0.7% per year after 2000), so that the Canadian population reaches a total of 31 million by the year 2000 and 37 million by 2025 (Table 2.1). The number of households grows more rapidly than does population because family size is declining; the number of people per household falls from 3.2 in 1978 to just under 2.6 in 2025, though in this case most of the fall occurs by 2000. In part because of shrinking household size and in part because of changing preferences and costs, there has been a trend away from single-family detached houses to various kinds of attached dwellings and apartments. As shown in Table CA-3, this trend was continued, though at a declining rate, in the projections.

Other trends accompany those in population and household size, including growing participation by women in the labour force and changing age structure with a lower proportion of young people and a higher proportion of older. These trends combine to indicate that the share of the population defined statistically as dependent (those under 15 and over 65) will decline until after the turn of the century and then begin to climb; conversely, the share of people in the labour force grows until after the turn of the century and then begins to fall.

Economic Activity

Many features of the economy are the same in the two scenarios, including the efficiency and location of economic activity, ownership patterns and industrial technology. However, the two scenarios do vary in the volume and, to a smaller extent, the nature of output. In the Consumer Saturation scenario increased growth in goods and services is moderated by a shorter work year in order to maintain full employment. Thus, "increasing productivity is taken in the form of a moderate increase in GDP per person and a healthy increase in leisure time" (McInnis and Trepanier, 1979, p. 11). In contrast, in the Business as Usual scenario increased growth is moderated for only selected goods and services; others continue to grow enough to absorb the increasing labour productivity and to maintain full employment without any change in the work year. Thus,

> "labour productivity gains are all absorbed by increasing the consumption of nominal goods and services,...thereby increasing the GDP per person...while leisure time remains constant" (Ibid.).

In the Business as Usual scenario, aggregate labour productivity rises at about 1.1% per year , about a 70% increase over the 47-year period (Table 2.3), while the total number of labour hours per year is held at its original level. As a result, GDP and GDP per capita go up by 2.6% per year and 1.6% per year, respectively -- tripling for the former and doubling for the latter. Consumer expenditures rise by about 1.7% per year, increasing by 2-1/4 times over 47 years. In all cases the growth rate falls off after 2010[1], so that most of the effects are felt in the first two-thirds of the period under consideration here. Thus, GDP grows by 4.3% per year, and GDP per capita by 3.0% per year, from 1978 to 2000 -- rates high enough to have ramifications for the results obtained.

Life under the Consumer Saturation scenario would not be radically different from that under the Business as Usual. Aggregate labour productivity grows at essentially the same rate as than in the Business as Usual scenario, but the work year falls by about 30% during the same period. Thus, the work year in 2025 might be made up of four 7-1/2 hour days per week with seven weeks of holidays per year (Ibid.). As a result of this change in working patterns (and presumably in values), GDP grows by "only" 1.9% per year, GDP per capita by 0.9% per year and consumer expenditures on goods and services by 1.0% per year. GDP would therefore increase by a factor of 2-2/5, GDP per capita by half, and consumer-expenditures by three-fifths over the 47 years of our study.

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[1] The reasons for this involve complexities in the operation of the model rather than anything inherent in the projections.

Lifestyles

Both economies are projected to be richer than those of today in material goods and purchased services, though the increase is of course greater in the Business as Usual than in the Consumer Saturation scenario. The difference lies not so much in the availability or purchases of consumer durables as in their intensity of use and in the use of services, both of which are higher in the Business as Usual scenario. Not only do people in that scenario drive more kilometres per year on the average, but they require more automobile servicing and they drive their automobiles to stores, recreation areas and schools where they demand (and pay for) additional services. On the other hand, they also use public transportation, recycle goods and buy the same sorts of houses, autos and appliances as people in the Consumer Saturation scenario.

In rough terms, people living under conditions modeled in the Business as Usual scenario opt to work about 40% more in order to be able to spend about 40% more than those in the Consumer Saturation scenario. The choice between the two scenarios is thus not economic but political. Both economies "work"; both are rich, stable and characterized by full employment. There is nothing except the future values of Canadians to say which is preferable. Indeed, there is nothing to say that Canadians could not opt for higher or lower rates of economic growth than those portrayed in the two scenarios. As emphasized above, the Business as Usual and Consumer Saturation scenarios bracket a modest range; above the former is all-out material growth and below the latter is the conserver society. The economies that have been chosen in order to illustrate the soft energy option for Canada are entirely recognizable. Apart from some obvious technical differences -- smaller vehicles, more apartments etc. -- it would be hard for a casual observer some 50 years hence to see much that is different in the futures that are projected here from the Canada of today.

3.3 ENERGY USE IN 2000 AND 2025

The single most important finding of this study is that, despite sustained economic growth and modest population growth, very little more energy needs be used in 2000 than was used in 1978 provided only that cost-effective conservation measures are implemented at a reasonable rate (Business as Usual scenario). If one looks further into the future, secondary energy use would actually peak about year 2000 and would, under the same conditions, decline sufficiently thereafter to make the overall trend between 1978 and 2025 negative. Given these results, it is hardly surprising that, if economic growth is cut back somewhat and modest lifestyle changes introduced (Consumer Saturation scenario), secondary energy growth is negative over the whole projection period. The quantitative results are summarized in Table 3.1.

TABLE 3.1

AVERAGE ANNUAL RATES OF GROWTH FOR SECONDARY ENERGY USE
(percent per year)

	Business as Usual	Consumer Saturation
1978 - 2000	0.2	-1.1
2000 - 2025	-0.7	-0.7
1978 - 2025	-0.3	-0.9

It cannot be emphasized too strongly that the feasibility of very low or negative energy growth, as identified in this study ,does not depend upon declines in the economy. much less on declines in productivity. Rather, it depends exclusively (in the Business as Usual scenario) and largely (in the Consumer Saturation scenario) upon gains in energy efficiency, which have exactly the same positive economic effects as gains in labour productivity. Thus, in our projections, Canada's energy efficiency (or productivity) would climb from $43 of economic activity per gigajoule of secondary energy use in 1978 to almost $160 under either Business as Usual or Consumer Saturation conditions in 2025 -- a gain of three to four times over 47 years.

Within the results for total secondary use, sectoral use grows most unevenly. Residential use drops sharply and by 2025 is little more than half its level in 1978. Commercial use follows a similar pattern but at a more moderate rate of decline. For both sectors most of the decline occurs in the first half of the projection period. In contrast to all other sectors, industrial use is higher in 2000 than in 1978 in the Business as Usual scenario (and holds steady in the Consumer Saturation scenario). However, it too begins to fall after 2000, and it is this "hump" that explains the positive rate of growth for total energy use between 1978 and 2000 in the Business as Usual scenario. Finally, although energy use in the Transportation sector falls steadily in both scenarios, the rate of decline is much less in the Business as Usual than in the Consumer Saturation scenario. The quantitative results for each of the four sectors appear as time series in Tables CA-4 through CA-7. Tables CA-8 through CA-11 and Figures CA-4, CA-5, CA-7, and CA-8 combine the sector-by-sector results to provide a cross-sectional look at secondary energy use (one table and one figure for each of the two scenarios in 2000 and in 2025). The tables provide totals by sector and quality as well as by the forms that supply the end uses.

Residential Sector

The Residential sector is defined in this study to include all dwelling units. This definition may seem self-evident, but it requires two adjustments from that used in many statistical tables. First, farming activities (though not farm houses) have been placed in the Industrial sector; Federal statistics avoid an admittedly difficult problem of separation by defining the sector as "Domestic and Farm". Second, all apartment units are placed with the Residential sector; in many tables, particularly those compiled from utility billing data, larger apartment buildings turn up in the Commercial sector. Also, special attention was paid to ensure that mobile homes were not neglected.

In 1978 there were some 7.6 million households in Canada. This figure grows to 11.3 million in 2000 and 14.2 million in 2025, according to the projections used here (which, as will be recalled, are the same for both scenarios). Our analysis categorizes the residences as single-family detached, attached units (including vertical and horizontal duplexes and row housing), apartments or mobile homes. Although some provinces were able to obtain finer breakdowns, this fourfold classification was used for national compilation of residential energy data because opportunities for energy conservation are fairly uniform within each category.

Energy is used in the Residential sector for three main purposes: space heating, water heating, and lighting and appliances. The first two fall entirely into the Heating and Cooling quality (though air conditioning is small); lighting and appliances are all treated as Electricity Specific (though much of this energy really involves low-temperature heat, as with refrigeration).

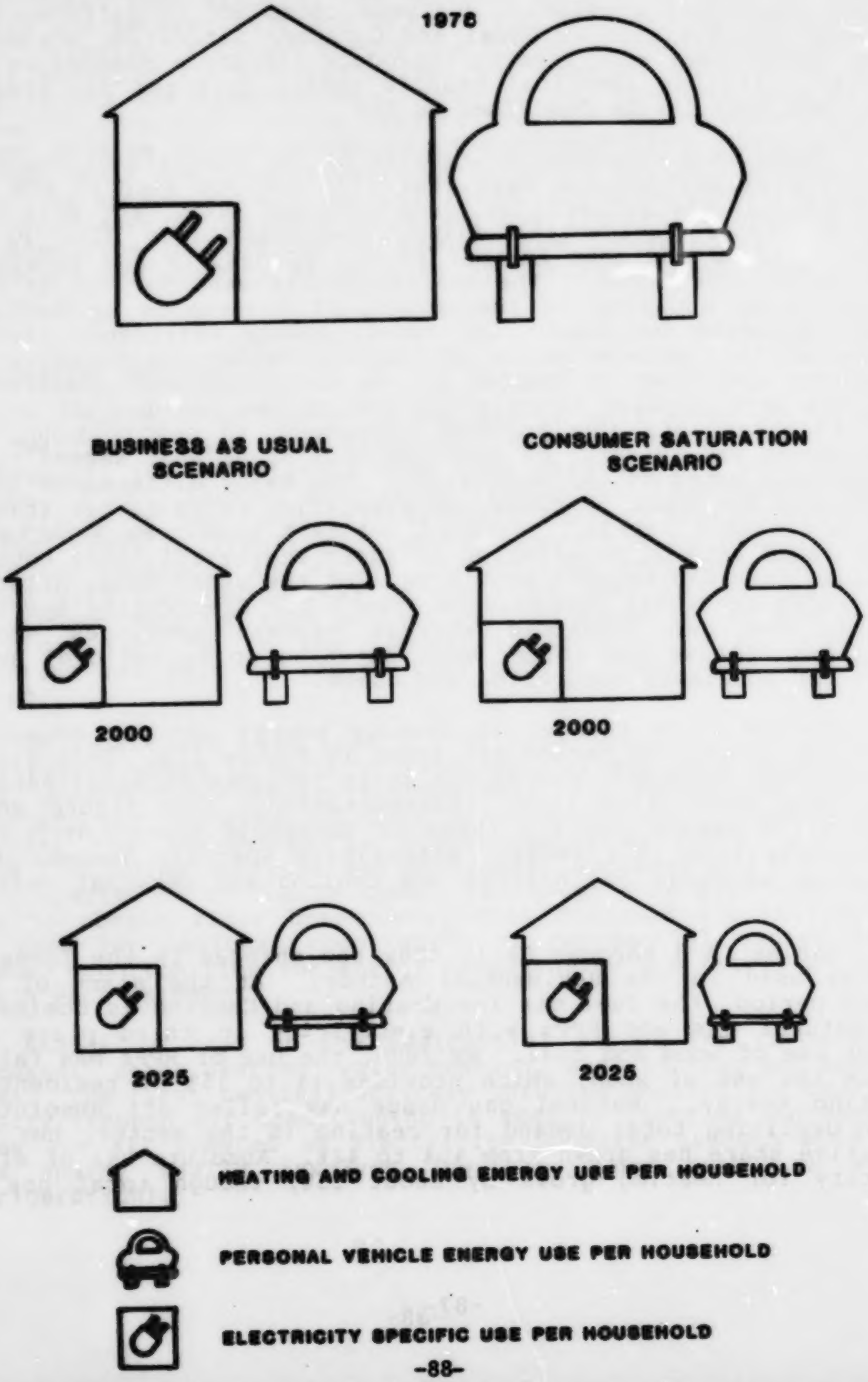
Even during the period of rapid energy growth in the 1960s, energy use in the Residential sector lagged. This trend continues in this analysis because of the enormous potential for saving energy through technical fixes in the thermal integrity of structures and in appliance efficiency. So great was this effect that most provincial analysts chose not to differentiate between the Business as Usual and Consumer Saturation scenarios even though they were free to introduce lifestyle changes in the latter. All but identical results obtain with the two scenarios, and they can be described as one.

Table CA-4 provides the results of the analysis of residential energy use for the base year 1978 and for each of the two scenarios in the projections years 2000 and 2025. For both scenarios, total residential energy use falls from 1270 PJ to around 840 PJ and then further to 670 PJ despite the growth of population and income. The energy results were derived in each province by applying to the growth of households by dwelling type, adjusted for demolition rates, energy efficiency factors based on the implementation of the cost-effective conservation measures specified in Chapter 2. As indicated there, different factors were applied to existing and to new residential units, and each province incorporated investment in new housing, new appliances and retrofit of existing housing at what seemed to be reasonable rates of implementation. The major differences among provinces are found in those implementation rates rather than in the efficiency levels. Notably, western provinces expected a more rapid rate of penetration of super-energy-efficient housing designs than did eastern provinces. On the other hand, Atlantic provinces generally showed some growth for Electricity Specific energy use per household whereas western provinces showed declines because the former were catching up to national averages for appliance saturation and usage.

The relative changes in average energy use per household over the projection period are shown in Figure 3.3. This figure shows total household energy use so it includes personal vehicle use, discussed below under transportation. The figure shows that while demand for all types of household energy drop substantially from 1978 levels, Electricity Specific demands grow relative to those for Heating and Cooling and personal vehicle use.

Tables CA-8 through CA-11 show the changes in the forms of energy used in the Residential sector. At the start of the study period, the fuel mix for Heating and Cooling is dominated by natural gas and RPPs with electricity in third place and minor use of wood and coal. By 2000, the use of RPPs has fallen below the use of wood, which provides 14 to 15% of residential heating energy. Natural gas usage has fallen off absolutely with declining total demand for heating in the sector, but its relative share has grown from 40% to 42%. Absolute use of electricity for heating grows by about 15%, though total use of

FIGURE 3.3
AVERAGE SECONDARY ENERGY USE PER HOUSEHOLD



electricity including Electricity Specific uses, grows by only about 6%. Its rise to become the second most important heating fuel is a result of several factors, including continued conversions to electricity in some provinces, electrical back-up in super-energy-efficient residences and the fact that today's all-electric homes tend to be relatively new so that few of them are expected to be demolished between now and 2000. Active solar heating provides about twice as much energy in the year 2000 as wood and coal together provided in 1978, and biogas about as much as wood alone in 1978. Between them biogas and active solar account for about 9% of residential heating in 2000.

By 2025 the same trends have been carried further, and some differences have appeared in the two scenarios as use of renewable sources is pursued more vigorously in Consumer Saturation. Natural gas usage continues to fall, and electricity usage also falls, despite growth of electric heating in some provinces and electrical back-up in all. (Electricity for Electricity Specific use remains almost constant over the entire period in both scenarios; this result implies that the increased efficiency of lighting, appliances and ventilation systems has balanced increased usage and sales.) Use of wood for heating has grown only 25 to 30% over that in 2000, but energy derived from active solar systems has doubled and that from biogas has gone up by 2-1/2 to nearly 4 times depending upon the scenario. (The latter shift leads to some anomolous results: for some provinces energy use is higher in the Consumer Saturation scenario than in the Business as Usual scenario because the efficiency of biogas systems in the former is less than that of natural gas systems in the latter.) The changes in the shares of energy forms used for residential heating are shown in Table 3.2.

TABLE 3.2

SOURCES OF ENERGY FOR RESIDENTIAL HEATING AND COOLING
(percent)

		Business as Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Natural Gas	38	42	24	44	18
RPPs	47	10	3	6	1
Electricity	14	25	24	25	23
Biomass Solids	2	14	24	15	26
Biomass Fluids	-	3	8	3	13
Active Solar	-	6	16	7	18

In summary, apart from the greater proportion of apartments and the greater density of cities--and perhaps the reflection from roof-top solar collectors--the casual observer would not notice much different in the Residential sector portrayed here for 2000 and 2025 than the one he or she knew in 1978. However, such a person would have missed the single overriding change in the character of the housing: viz., greater efficiency. The number of housing units has grown but energy use has fallen, as indicated in Table 3.3.

TABLE 3.3

AVERAGE ANNUAL SECONDARY ENERGY USE FOR HEATING AND COOLING PER HOUSEHOLD
(gigajoules per year)

	1978	2000	2025
Single Family Detached	176	70	42
Attached	117	48	31
Apartments	97	48	30

These gains are of course sensitive to the assumptions about energy prices and construction costs. If the former are lower or the latter higher than assumed, cost-effective energy savings will be reduced. However, those savings are so substantial and so cost-effective that rather large shifts in other variables are required to alter the results very much. For example, in a sensitivity analysis for Prince Edward Island a one-third increase in costs cut energy savings by only about 5%. Indeed, most provincial reports identified additional opportunities not included in this study for cost-effective gains in residential energy efficiency, particularly with water heating (which takes a greater and greater share of heating and cooling energy as space heating needs decrease).

Commercial Sector

As indicated in Chapter 2, the Commercial sector commonly becomes a catch-all in energy statistics for a variety of activities including large residential complexes and light manufacturing. In this study, attempts were made to limit the sector to office buildings, educational and medical facilities, hotels, shops and other service industries plus street lighting. In effect, most government activities fall into this sector. So far as energy use is concerned, the real problem was not so much projecting the economic growth of the sector as relating this to physical growth in terms that could in turn be related to energy use. Differences in the availability and quality of data on the Commercial sector among provinces were so great that resolution of the problem had to be dealt with at that level.

The Commercial sector has been growing rapidly by whatever measure is used, something that is quite evident to anyone watching the changing skyline of Canadian cities. In energy terms it was one of the fastest growing sectors during the 1960s and early 1970s. The Commercial sector continues to grow strongly in our projections, which reflects the surprise-free nature of the model in that trends toward urbanization, centralization of service functions and, at least in the Business as Usual scenario, monetization of services are continued. However, economic growth in the sector is by no means reflected in energy growth, for in the large buildings that dominate sectoral energy use the possibilities for conservation are little short of prodigious.

Table CA-5 shows the projections of energy use in the Commercial sector by subsector, scenario and energy quality. (Because some provinces could not find data broken down appropriately, there is a large unallocated block in Table CA-5.) The changing mix of energy forms used can be found in Tables CA-1 and Tables CA-8 to CA-11. Energy use declines absolutely for all cases: from 810 PJ in 1978 to 580 PJ in the Business as Usual scenario and 420 PJ in the Consumer Saturation scenario. In terms of average growth rates, the figures are -0.7%/a and -1.3%/a. Office buildings show a slight increase in energy use in the first half of the period to 2000, which reflects both growth in the sector and the fact that greater gains in energy efficiency are possible when constructing new buildings than when improving existing ones. It takes a number of years before many office buildings, hospitals and hotels can reasonably be expected to be replaced (buildings have an average life of 45 to 50 years), no matter how energy inefficient they may be. Growth rates in the Commercial sector would have been even lower but for shifts among subsectors. For example, the LTSM reacts to the increasing average age of the Canadian population by increasing the need for hospitals, which is one of the most intensive users of energy in the sector. In short, differences among subsectors in Table CA-5 are a resultant of different growth rates and different potentials for conservation. Differences between the two scenarios stem exclusively from different growth rates as efficiency gains were the same in each. However, in contrast to the Residential sector, those gains may be more sensitive to price and cost changes; in one test a 50% increase in cost reduced cost-effective energy savings by 20 to 30%, a result that would have greater impact on retrofit than on new construction.

The nature of energy conservation technologies applied in the Commercial sector is strongly reflected by the changing energy qualities used. Just as with the Residential sector, these are limited to Heating and Cooling and Electricity Specific. Over time the latter increases its share of total sectoral use from 27% to 51% to 53% as building design eliminates the need for any outside source of space and water heating in favour of moving energy around with pumps and fans. As a result big buildings tend to become all-electric. (An alternative approach involves use of total energy systems based on natural gas or biomass, but this technology played a relatively small role in our study.) With the eventual replacement of all inefficient structures (heritage buildings excepted), the ultimate elimination of Heating and Cooling energy in the Commercial sector is quite feasible.

The fuel mix for Heating and Cooling in the Commercial sector also changes with time. At the start, the sector is supplied mainly from natural gas (55%), RPPs (40%) and electricity (5%). By the year 2000, use of natural gas has been cut by 30% and of RPPs by 80%; in contrast, electricity usage has grown by half to provide 10% of heating and cooling needs, and wood and active solar systems each provide 8% to 10%. (These percentages are for the Business as Usual scenario. The same trends also obtain in Consumer Saturation but, with lower total demand, use of RPPs is almost totally eliminated, electricity fails to increase and renewables provide 10 to 12% of Heating and Cooling energy.) By 2025, use of natural gas fallen another 30% but is still the main source of Heating and Cooling energy, active solar systems are in second place, RPPs play essentially no role, and electricity, biomass solids and biogas follow in that order. Including Electricity Specific uses, electricity gradually becomes the dominant form, though in absolute terms only one-third more is being used than in 1978 (no more in the Consumer Saturation scenario). Wood usage never climbs much above its role in 2000 (it actually declines after 2000 in Consumer Saturation), but, along with biogas and peat, works in situations where there is a nearby source and the opportunity for cogeneration.

Provincial variations in the patterns of energy use in the Commercial sector reflect mainly different rates at which energy-efficient designs were considered likely to be implemented and different rates for new construction in the sector. Thus, Alberta could look forward to a five-fold increase in commercial activity, most of it concentrated in urban centres, but anticipate a decline of over 20% in energy use (though an increase in electrical use) for the sector. In contrast, Prince Edward Island with a slower rate of growth and a greater share of existing buildings in the future mix, anticipated a slight increase in sectoral energy use. Most provinces followed the national pattern of a slow decline in Commercial sector energy use to 2000 and then a sharper decline between 2000 and 2025.

Greater variations are found in the mix of energy forms, as will be described further below.

Just as with the Residential sector, the overriding difference in the Commercial sector between 1978 and 2000 or 2025 is energy efficiency. Unfortunately, because of the absence of good national data on the physical size of the sector and the large unallocated block of energy in the tables (which means that subsector totals are incomplete), no estimates are possible for the specific energy efficiency of either the sector as a whole or of its subsectors. (Some provincial estimates were possible; see Volume II.)

The gain in energy efficiency will, of course, be imperceptible to most observers. They will notice more daylighting within buildings, and see that the monotonous similarity of facades on today's buildings has been replaced by facades that vary with compass direction. What they will not see is the extensive computer control of building operations, nor will they be aware of the careful design that has gone into making the building energy efficient--and also attractive and comfortable.

Industrial Sector

As described at some length in Chapter 2, for both conceptual and statistical reasons, the Industrial sector is the most difficult to analyze, yet in many ways is the most important. Not only is it the largest energy using sector today, but most soft energy studies, including this one, find that it is likely to become even more dominant in the future. (By 2025, the Industrial sector in this study accounts for almost half of total secondary energy use.) It is also the only sector where all energy qualities and all energy forms are used.

The study focused on the twelve major energy-using subsectors of industry and lumped the remainder of the sector into an "Other Manufacturing" category. All of the subsectors were projected forward within the LTSM model (Table 2.2). As specified above, the LTSM adjusts industrial output to reflect changing purchasing patterns in the two scenarios, both of which incorporate some shift away from goods to services, and the location of industry within Canada is shifted to reflect the growing manufacturing base in western provinces. Overall, the projection yields somewhat less resource dependent, more industrialized and regionally better balanced Canada, but not one whose industrial structure is markedly different from that in Canada today.

Table CA-6 shows the projected growth in energy use in each subsector of the Industrial sector by quality, year and scenario. Cross-sectional breakdowns by quality and form for the sector as a whole may be found in Tables CA-1 and CA-8 through CA-11. Immediately apparent from these tables and from Table

3.4 below is the relatively strong positive growth shown in the Business as Usual scenario to the year 2000 compared with zero energy growth in the Consumer Saturation scenario and with the decline in energy use for both scenarios after 2000.

TABLE 3.4

ANNUAL RATES OF GROWTH OF SECONDARY ENERGY USE IN THE INDUSTRIAL SECTOR
(percent per year)

	Business as Usual	Consumer Saturation
1978 - 2000	+1.6	0.0
2000 - 2025	-0.8	-0.8
1978 - 2025	+0.3	-0.4

Thus, it is the industrial sector that is responsible for the year 2000 "hump" in the overall results for secondary energy use portrayed in this study. More fundamentally those results reflect the strong economic growth assumed for the 1978 to 2000 years.

Almost every province exhibits a humped pattern for industrial energy use similar to that shown just above; in other words, the national pattern reflects more than the dominance of Ontario and Quebec in the data. Much greater variations appear in the ratio of industrial energy use to total secondary energy use by province. Here national results are dominated by Ontario and Quebec, whose industries each use about 35% of the total. However, the range in this industrial share extends from 9% (Prince Edward Island) to 53% (British Columbia), with a number of provinces falling in the 20 to 30% portion of the range.

With one major exception, the changes over time in the use of energy qualities in the Industrial sector parallel that for total industrial use. The exception involves the use of High-Temperature Process Heat which grows more rapidly to the year 2000 than does total industrial energy--by +2.1%/a and +0.5%/a in the two scenarios--and it falls off less in the second half of the study period. Over the 47 years to 2025, use of High-Temperature Process Heat grows by 50% in the Business as Usual scenario and by only 4% in the Consumer Saturation. As a result it grows from taking 30% to 39% of all industrial energy. This gain occurs largely at the expense of Intermediate-Temperature Process Heat, which drops from 35% to 28%.

Other changes in energy quality categories used by industry are less important. The shares accounted for by Heating and Cooling (which includes low-temperature process heat), by Intermediate-Temperature Heat and by Liquid Fuel all decline a little, and the share accounted for by Electricity Specific stays constant. These changes might have been larger but for the assumption, made in the absence of better information, that quality shares within any industrial subsector would not change with its output. In particular, one would have expected that more of the low-temperature and mid-temperature heat would be provided from various waste heat sources and thus drop out of the statistics, which as noted in Chapter 2 represent purchased energy. (Incorporating this effect would not, of course, have altered the absolute amounts of high-temperature energy qualities required, only their shares.) For the most part, the two scenarios exhibit similar results with respect to quality. However in those provinces with a lot of heavy manufacturing (e.g., Ontario), the effects identified above are greater in the Consumer Saturation than in the Business as Usual scenario.

Within the overall pattern of growth, different subsectors exhibit quite different energy results. A few, such as agriculture, forestry and food processing show no growth or declining energy use over the whole period; others, such as mining and the metals industries, show a still sharper hump than the average. However, with the exception of iron and steel, all decline in energy use after 2000.

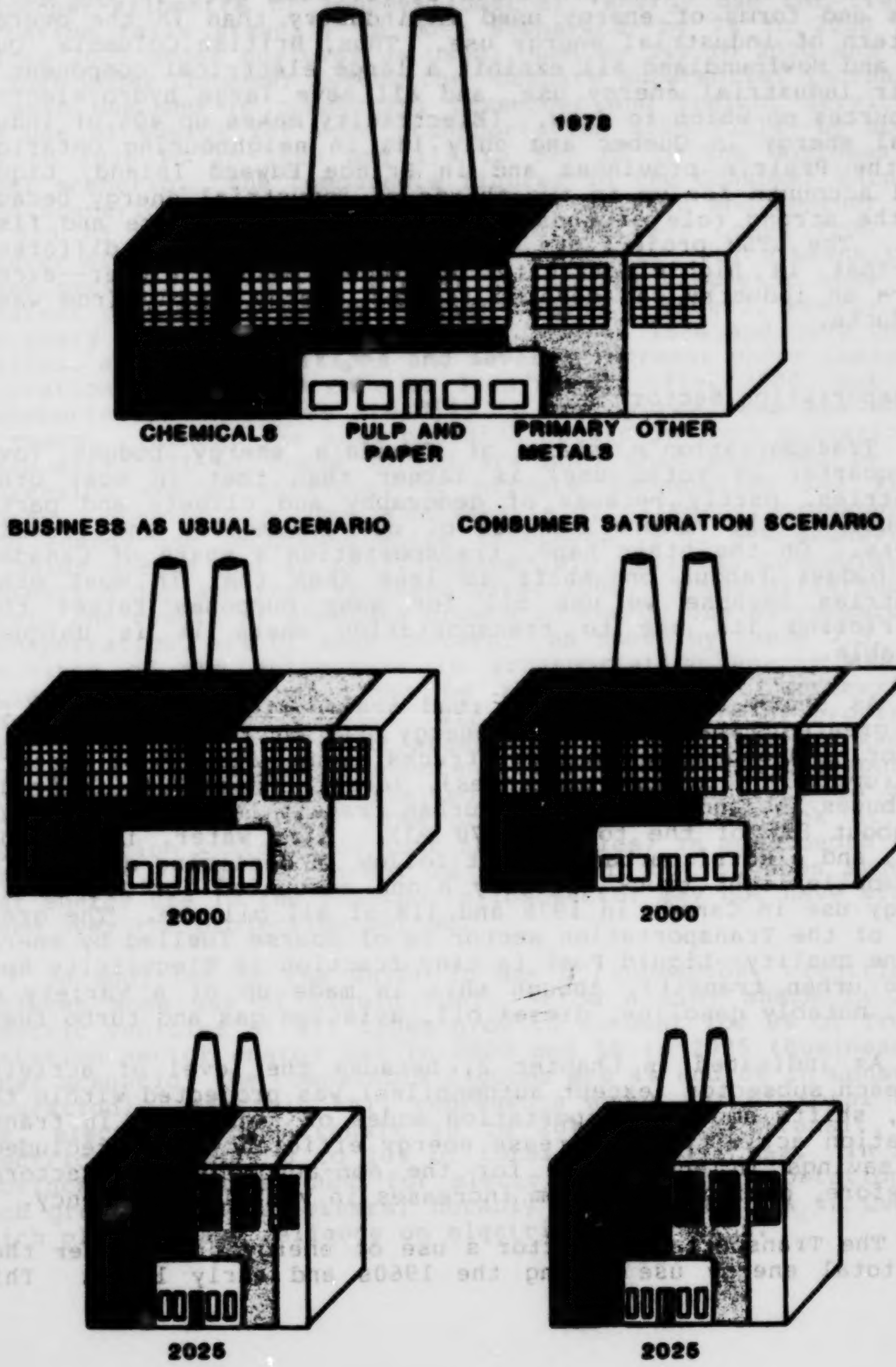
The varying rates of growth among industrial subsectors interact to maintain the dominance of energy use by a few energy-intensive subsectors, in 1978 three subsectors (pulp and paper, iron and steel, chemicals) accounted for 46% of total energy use; if agriculture and smelting and refining are added, the share grows to 62%. By 2025 the same groups of industries account for 46% and 64% of total use, respectively (Business as Usual scenario). High-Temperature Process Heat shows the same effect: in 1978 four subsectors (pulp and paper, iron and steel, smelting and refining and chemicals) use 60%; in 2025 the same subsectors take almost 70%. In part, these results stem from the LTSM which pushes out all sectors without allowance for resource limitations. (The projection for steel production in Ontario, for example, is likely to be too high given recent trends to other materials and economies in the use of steel itself. The projection for pulp and paper production in British Columbia is surely too high because the industry is facing the end of new timber land.) However, the results also stem from the more evident conservation potential for low- and mid-temperature process heat, which are exactly what the less energy-intensive subsectors tend to use.

The figures to now have, of course, referred simply to industrial energy use without taking account of output. Figure 3.4 shows the changes in industrial energy use per dollar of output over the projection period. It is apparent that while all subsectors shown there substantially reduce their energy intensity, the relative reductions are much less for primary metals than for the rest of industry. When energy use is compared with the value of output, the efficiency gains projected in this study imply a price elasticity of demand of only about -0.34. Given that most analysts find that the price elasticity for energy in industry is below -0.5 (Berndt and Wood, 1975; Pindyck, cited in Ross and Williams, 1981, p. 277), one can argue that, even if energy prices are lower or conservation costs higher than have been assumed in this study, the projected results would not change very much.

So far as energy forms are concerned, industrial use in 1978 was well distributed among natural gas, RPPs and electricity, with coal and wood providing about 8% each. The wide distribution of use among forms continues throughout the projection period, but the forms change dramatically. Coal usage doubles in the Business as Usual scenario (up by 70% in Consumer Saturation) largely because of the demands from the steel industry for High-Temperature Process Heat. Natural gas usage rises by over one-third to the year 2000 in the Business as Usual scenario and then falls off, but it still accounts for 11% of industrial energy in 2025; in the Consumer Saturation scenario natural gas usage falls over the whole period and is almost out of the picture (4% of industrial energy) by 2025. Whenever it is used, it is one of the main sources for Medium- and High-Temperature Process Heat. Use of oil products falls steadily; there is only minimal usage by 2025 in either scenario; even by the year 2000, use of RPPs has been cut by half in the Business as Usual scenario and by two-thirds in Consumer Saturation. Electricity is the most stable form of all; it retains its share of about 20% of total industrial energy use in both scenarios. Over time a little less of the electricity goes to produce heat, and more is used for Electricity Specific functions. Biomass solids play a small role in 1978, mainly in the pulp and paper industry. Usage grows sharply in both scenarios to 2000, by which time biomass solids are the second most important form used in the Industrial sector. They show little growth thereafter but, with the decline of other forms, biomass solids rank first in use in 2025. At first this biomass is mainly used to produce Mid-Temperature Process Heat, but by 2025 more than one-third is going to produce High-Temperature Process Heat. Biomass Fluids play a modest role after 2000, largely to replace those RPPs that were providing the 12% or so of industrial energy needed in the form of Liquid Fuel (mainly for mobile equipment and internal transportation systems). Finally, active solar is negligible in 2000 but provides 5% of sectoral use in 2025; in absolute terms it accounts for about as much energy then as wood in 1978. Of course, had our analytic method not ruled out, as a conservatism, the use of active solar systems for pre-heating of higher temperature process heat, this figure could have been much higher.

FIGURE 3.4

INDUSTRIAL ENERGY USE PER DOLLAR OF OUTPUT



Because of differences in the industrial mix and the energy resource availability within their borders (two obviously related factors), the provinces differ much more in the qualities and forms of energy used in industry than in the overall pattern of industrial energy use. Thus, British Columbia, Quebec and Newfoundland all exhibit a large electrical component in their industrial energy use, and all have large hydro-electric resources on which to draw. (Electricity makes up 40% of industrial energy in Quebec and only 18% in neighbouring Ontario.) In the Prairie provinces and in Prince Edward Island, Liquid Fuel accounts for up to two-thirds of industrial energy because of the strong role of those provinces in agriculture and fishing. The LTSM projections tend to exaggerate these differences--that is high-electricity provinces become higher--except where an industry can develop its own energy supply from waste products.

Transportation Sector

Transportation's share of Canada's energy budget (over one-quarter of total use) is larger than that in most other countries, partly because of geography and climate and partly because of the nature and use of our automobile and trucking fleets. On the other hand, transportation's share of Canada's oil budget (about one-half) is less than that in most other countries because we use oil for many purposes rather than restricting its use to transportation where it is uniquely valuable.

As shown in Table CA-7, road transportation takes by far the greatest share of total energy use in the Transportation sector. Automobiles and light trucks alone take 59% of sectoral use (up to 70% in some provinces), larger trucks 20%, inter-urban buses 2%, and non-electric urban transit 1%. Total road use is about 82% of the total (1370 PJ). Air, water, inter-urban rail, and electric urban transit follow in declining order. The automobile/light truck category alone accounted for 17% of all energy use in Canada in 1978 and 31% of all oil use. The great bulk of the Transportation sector is of course fuelled by energy of one quality--Liquid Fuel (a tiny fraction is Electricity Specific urban transit), though this is made up of a variety of RPPs, notably gasoline, diesel oil, aviation gas and turbo fuel.

As indicated in Chapter 2, because the level of activity for each subsector (except automobiles) was projected within the LTSM, shifts among transportation modes or reductions in transportation activity to increase energy efficiency are precluded. Any savings in energy use for the non-automobile subsectors, therefore, derived only from increases in vehicle efficiency.

The Transportation sector's use of energy grew faster than did total energy use during the 1960s and early 1970s. This situation is quite reversed in the projections developed here. Largely because of greater specific efficiency (energy use per passenger-kilometre or tonne-kilometre), energy use for transportation falls steadily in both scenarios--by 7% to 2000 and 13% to 2025 under Business as Usual, and by 34% to 2000 and 41% to 2025 under Consumer Saturation--despite substantial increases in auto use and in commercial passenger and freight services. The use of energy for road transportation also falls--by about 22% to 1070 PJ in 2000 and 11% to 920 PJ in the Business as Usual scenario. The comparable figures in the Consumer Saturation scenario are a 44% fall to 770 PJ in 2000 and another 11% to 620 PJ in 2025. The bulk of this effect comes from the greater efficiency of the automobile subsector, which means that those provinces with the highest automobile subsector show the greatest decline in transportation demand. Indeed, energy use for every other subsector increases between 1978 and 2000 under Business as Usual conditions and several increase under Consumer Saturation. Most hold more or less steady after 2000, but air transportation increases steadily in energy use over the whole 47 years. (Almost the same patterns obtain in both scenarios.) Nationally, all of these shifts are more than balanced by the decreasing energy intensity of private automobiles and light trucks. However, in some provinces (e.g. Alberta) transportation energy use increases while in others (e.g. New Brunswick) it holds steady and in still others (e.g. British Columbia) it exhibits a dip and then recovers after 2000. These differences, mainly the result of absolute growth in energy use by commercial transportation, are of some concern. As shown by Table 3.5, the dominance of the automobile in transportation energy use is replaced in the projections by the dominance of commercial transportation (mainly truck, air and in a couple of provinces water). Whether this result stems from the fact that our knowledge about the conservation potential of commercial transportation subsectors is more limited, from our inability to make modal shifts within the LTSM or from a need to look at the transportation system (not just the vehicles) in more depth (or, most likely, from all three) is uncertain, but it does suggest that energy use in the Transportation sector may not have stabilized over the projection period.

In addition to the shift in use by subsector, electricity replaces some use of Liquid Fuel. From a tiny share in 1978 electric vehicles of all types grow to account for 3% of Transportation sector energy use in 2000 and 5% in 2025 (Business as Usual Scenario; the comparable figures are 4% and 6% in Consumer Saturation). Electric rail represents about 30% of total rail use, electric urban transit 15 to 20% of total transit, and electric automobile 5 to 10% of total automobile use. In some provinces, the role found for electricity in transportation is much greater than in others; notably it rises to 12% in Quebec which places heavy reliance on electric urban autos.

TABLE 3.5

PERCENTAGE DISTRIBUTION OF TRANSPORTATION ENERGY USE BY SUBSECTOR

		Business as Usual	Consumer Saturation
	1978	2025	2025
Air	8	19	19
Water	6	9	7
Rail	5	7	7
Heavy Truck	20	31	32
Inter-urban Bus	2	4	4
Urban Transit	1	3	2
Auto/light truck	59	27	26

Some impression of the gains in transportation energy efficiency can be seen in Table 3.6 which shows the results of some selected calculations that incorporate the effects of technology, higher load factors, and, in some cases, reduced usage. Similar information is displayed in Figure 3.5 which shows the growth in energy use and activity of each non-automobile transportation mode relative to 1978.

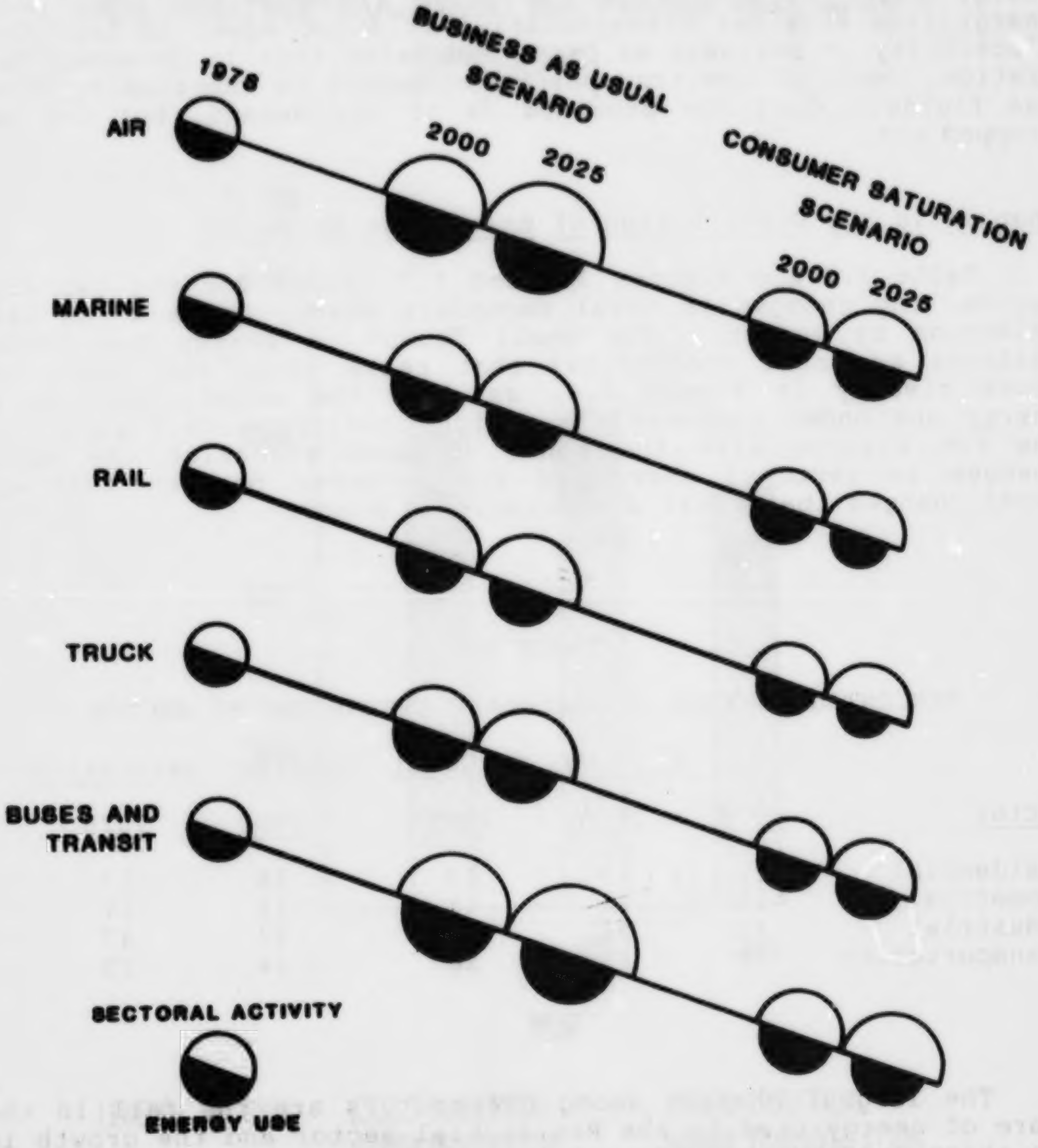
TABLE 3.6

ANNUAL ENERGY USE FOR SELECTED TRANSPORTATION SUBSECTORS

		Business As Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Energy Use per Automobile	.103	.043	.026	.034	.018
Energy Use per Dollar of Air Transportation	46	31	25	31	25
Energy Use per Dollar of Truck Transportation	64	41	32	41	32

FIGURE 3.5

GROWTH IN ACTIVITY AND ENERGY USE IN THE TRANSPORT SECTOR



While Liquid Fuel everywhere retains its dominance in the Transportation sector, a significant shift takes place in the sources of the Liquid Fuel. Initially, all comes from crude oil, but by 2000 biomass-based alcohol fuels have captured about 37% of sectoral usage in the Business As Usual scenario and 32% in the Consumer Saturation scenario. (The proportion is lower in the latter because the lower rate of energy use permits petroleum supplies to stretch further.) In that same year compressed natural gas (CNG) provides 2 to 3% of transportation energy and coal around 1% (in large steam ships). By 2025, energy from RPPs for transportation is about equal to that from electricity in Business as Usual and below that in Consumer Saturation. Most of the transportation demand is supplied by biomass fluids. Coal now provides 2% of the demand, but CNG has dropped out.

Changes in the Distribution of Energy Use by Sector

Table 3.7 and Figures 3.6 and 3.7 show, for the two scenarios, the changes in total secondary energy use and its distribution by sector. The small "hump" in energy use (under Business as Usual conditions) that peaks about the year 2000 shows clearly in Figure 3.6, as does the steady decline in energy use under Consumer Saturation conditions in Figure 3.7. The two figures also show that in both scenarios the major changes in sectoral shares of energy occur between 1978 and 2000; changes thereafter are relatively minor.

TABLE 3.7

PERCENTAGE SHARES OF SECONDARY ENERGY USE BY SECTOR

		Business as Usual		Consumer Saturation	
Sector	1978	2000	2025	2000	2025
Residential	21	13	13	18	17
Commercial	14	11	11	11	11
Industrial	37	51	48	47	47
Transportation	28	25	28	24	25

The largest changes among the sectors are the fall in the share of energy used by the Residential sector and the growth in the share used by the Industrial sector. Energy use in the Commercial sector declines slowly as rapid economic growth in this sector offsets in part improved construction practices. The

FIGURE 3.6

SECONDARY ENERGY USE IN CANADA BY SECTOR, BUSINESS AS USUAL SCENARIO

(PETAJOULES)

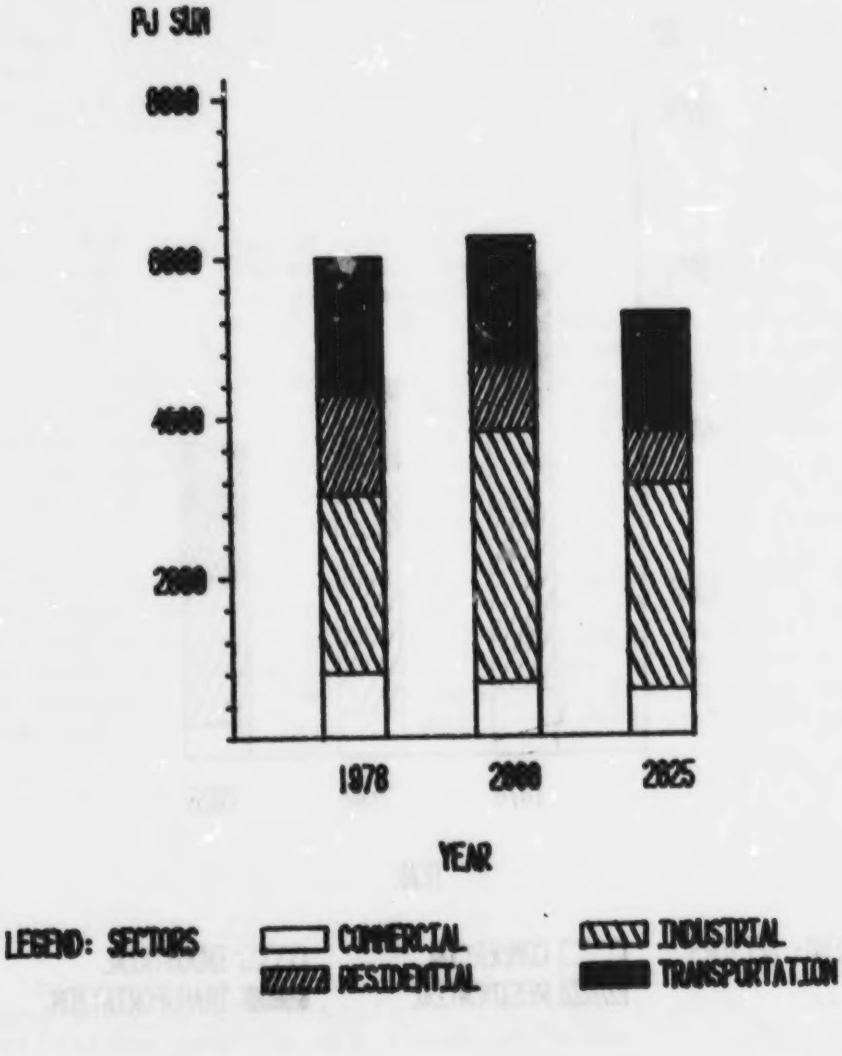
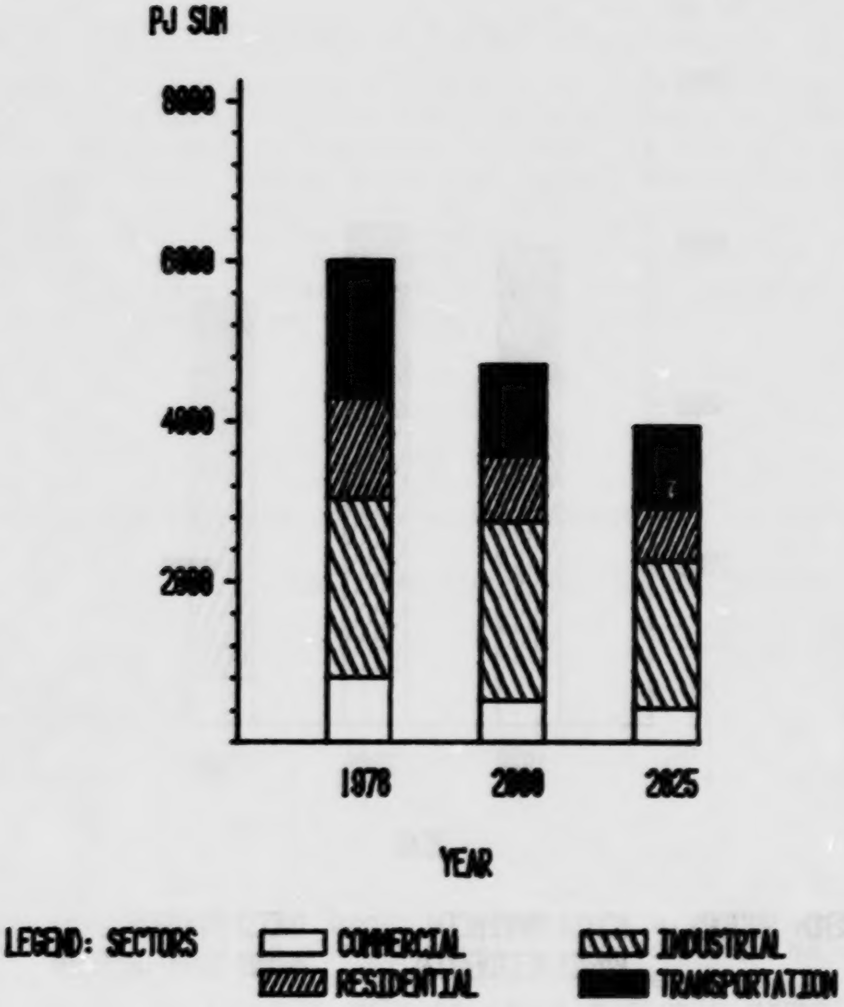


FIGURE 3.7

SECONDARY ENERGY USE IN CANADA BY SECTOR, CONSUMER SATURATION SCENARIO

(PETAJOULES)



share of energy used in the Transportation sector falls at first and then recovers, which reflects the growing role for commercial transportation and the relatively smaller efficiency gains projected for commercial vehicles than for automobiles.

For the most part, the changes exhibited by the two scenarios are very similar. Residential use retains a larger share under Consumer Saturation because new construction is lower. Similarly, the share of industrial use grows less because economic growth is lower. Also, the initial fall in the share for transportation is greater, and the subsequent rebound less, under Consumer Saturation because of reduced usage of automobiles and higher load factors in commercial transportation.

Changes in the Distribution of Energy Use by Province

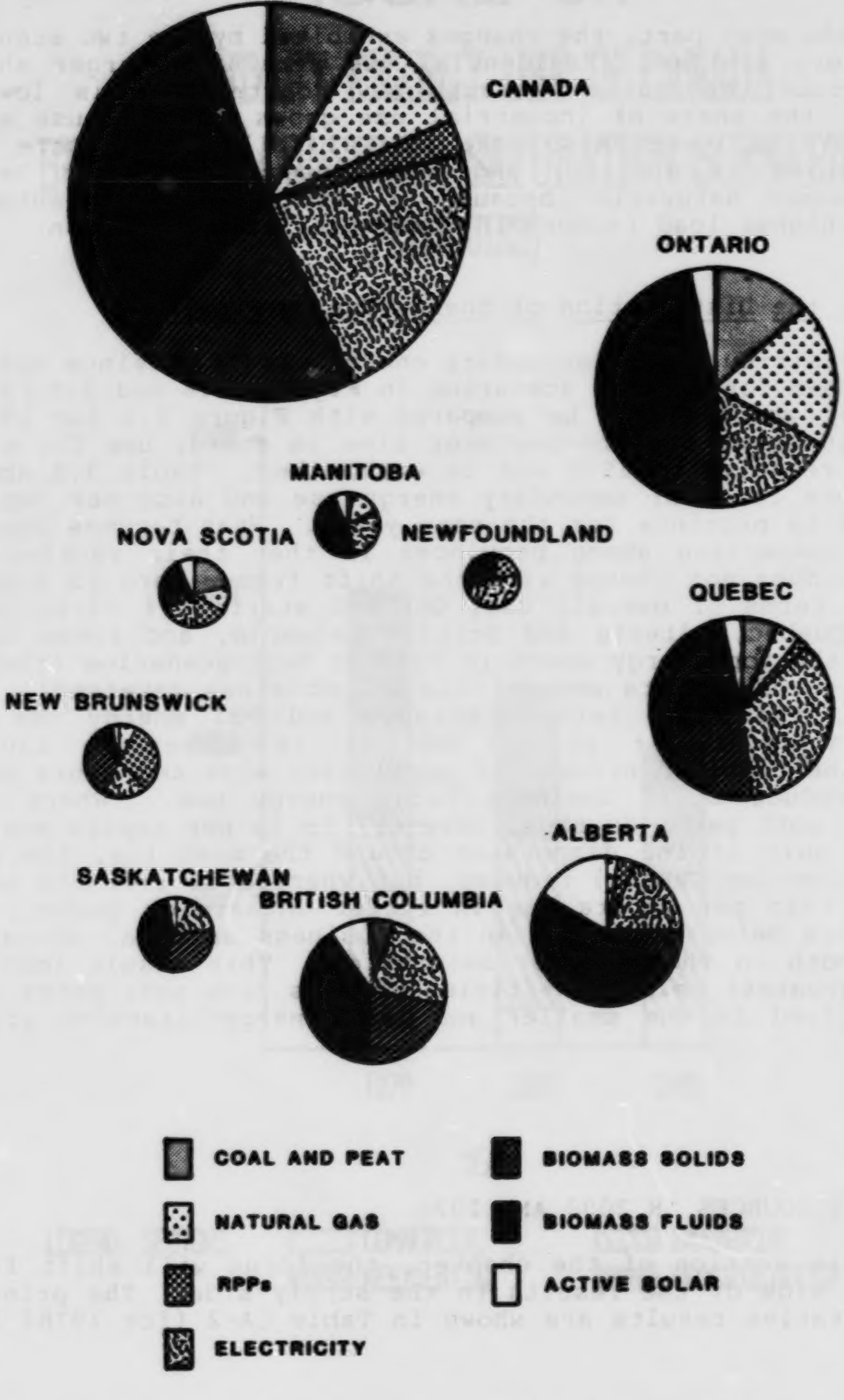
The distribution of secondary energy use by province and by form is shown for the two scenarios in Figures 3.8 and 3.9 (year 2025 only), which should be compared with Figure 3.1 for 1978. Figure 3.10 shows the changes over time in energy use for each province, relative to 1978 and to each other. Table 3.8 shows the absolute level of secondary energy use and also per capita energy use by province for the same years. What becomes apparent from comparison among provinces is that their ranking by energy use does not change with the shift from a hard to a soft path. In terms of overall use, Ontario starts off first followed by Quebec, Alberta and British Columbia, and these four are still the top energy users in 2025 in both scenarios (though the position of Alberta and British Columbia has reversed). At the start, the ratio between Ontario and PEI energy use is almost exactly 100:1; at the end it is closer to 130:1. Clearly, the combined effects of population size and gross provincial product still dominate total energy use. Where the effects of soft paths do show, however, is in per capita energy use. Not only is the dispersion around the mean (ie, the per capita figure for Canada) reduced, but whereas in 1978 the mean is higher than per capita use in either Ontario or Quebec, by 2025 it lies between the two in the Business as Usual scenario or below both in the Consumer Saturation. This result implies that the greatest relative efficiency gains from soft paths are being realized in the smaller and less energy-intensive provinces.

3.4 ENERGY SOURCES IN 2000 AND 2025

In this section of the chapter, the focus will shift from the demand side of the results to the supply side. The principal quantitative results are shown in Table CA-2 (for 1978) and

FIGURE 3.8

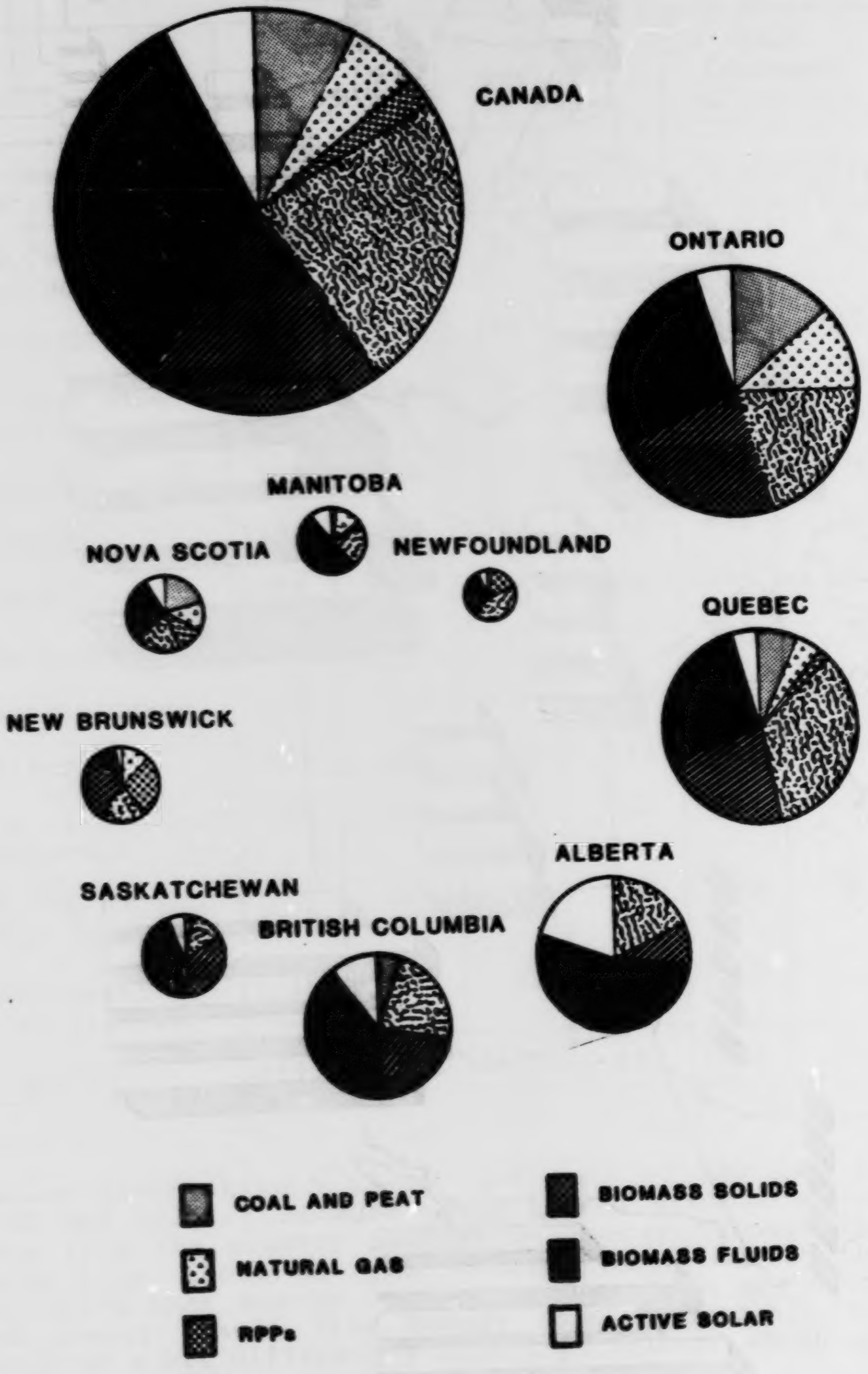
PROVINCIAL DISTRIBUTION OF SECONDARY ENERGY USE IN CANADA IN 2025, BUSINESS AS USUAL SCENARIO



NOTE: P.E.I. AND THE TERRITORIES ARE LESS THAN ONE PERCENT OF THE CANADIAN TOTAL

FIGURE 3.9

PROVINCIAL DISTRIBUTION OF SECONDARY ENERGY USE IN CANADA IN 2025, CONSUMER SATURATION SCENARIO



NOTE: P.E.I. AND THE TERRITORIES ARE LESS THAN ONE PERCENT OF THE CANADIAN TOTAL

FIGURE 3.10
REGIONAL SECONDARY ENERGY USE

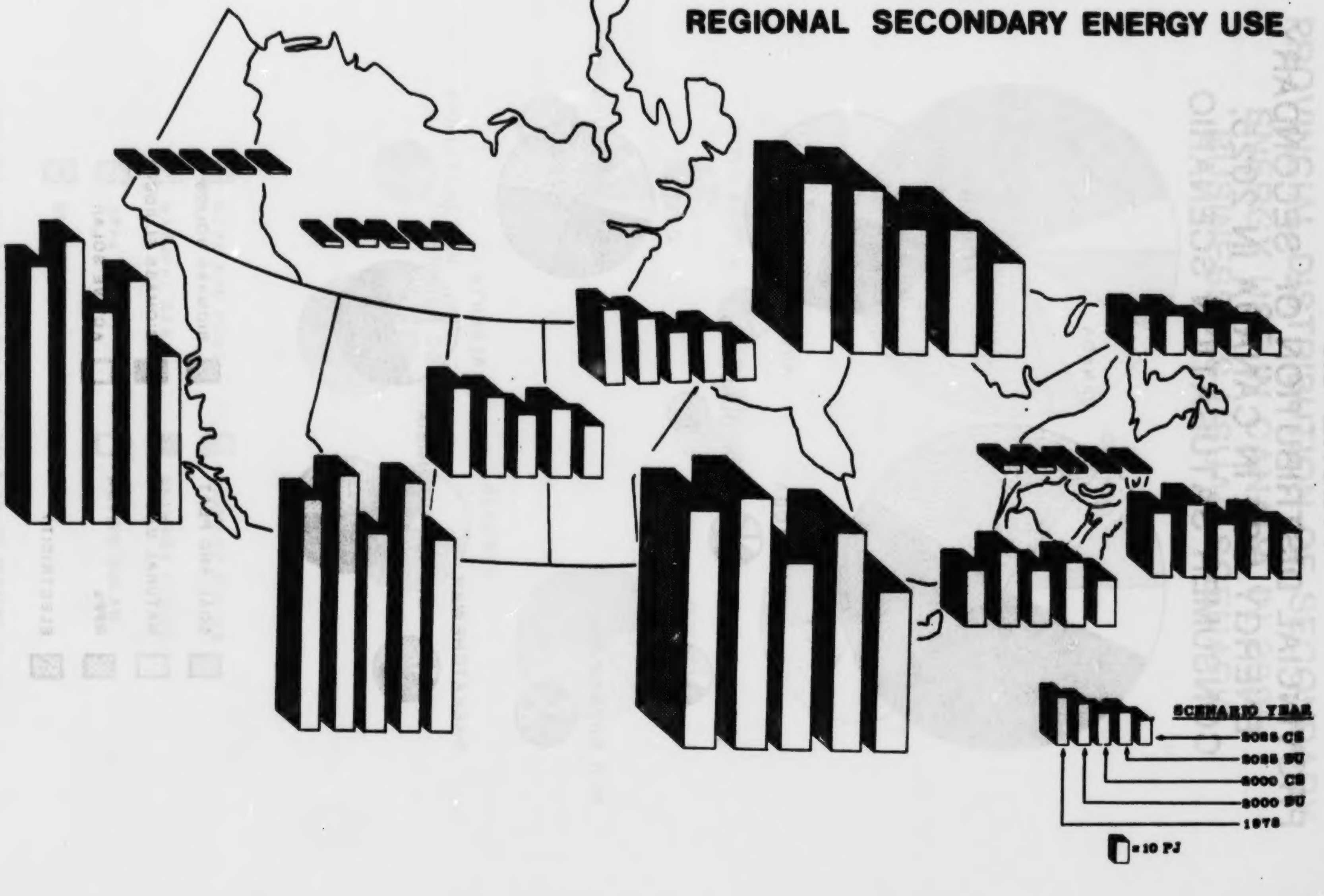

SCENARIO YEAR
2025 CS
2025 BU
2000 CS
2000 BU
1978
= 10 PJ

TABLE 3.8

TOTAL AND PER CAPITA ENERGY USE BY PROVINCE, 1978 AND 2025

(Total in petajoules; per capita in gigajoules)

Province or Territory	1978		2025 Business As Usual		2025 Consumer Saturation	
	Total	Per Capita	Total	Per Capita	Total	Per Capita
Newfoundland/ Labrador	114	200	99	120	67	81
Nova Scotia	184	219	166	137	134	110
Prince Edward Island	20	164	14	73	11	58
New Brunswick	167	240	192	190	137	136
Quebec	1494	238	1093	138	839	106
Ontario	2084	247	1921	152	1409	111
Manitoba	221	214	145	100	110	76
Saskatchewan	259	273	197	145	152	112
Alberta	669	342	723	143	557	111
British Columbia	756	299	704	139	489	97
Yukon Territory	9	363	12	288	9	117
Northwest Territories	15	317	23	337	15	145
Canada	5993	255	5289	143	3928	106

Tables CA-12 through CA-15 (for each of the two scenarios in 2000 and 2025). Because these tables present a snapshot of a flow from the primary sources of energy through the secondary forms (i.e. those that the consumer receives) to the end uses, including that energy used to produce both non-energy products and energy itself (the Energy Supply sector), they are constructed a bit differently from any table of which we are aware;

the reader is referred to Appendix 3.1 for general notes on how to use them. Finally, Table 3.9 shows how energy production and use characteristics change among the provinces.

This section is divided into six major subsections. First the general changes in energy production are discussed, by form and by province. Then a more detailed look at the sources is provided, subdivided into four categories: conventional and new nonrenewable sources and conventional and new renewable sources. Within this breakdown the approach to supply in the four latter subsections involves three partially implicit steps. First, the available supplies of energy resources are identified. This step is not exclusive to nonrenewable resources; hydroelectric sites are distinctly limited, as are good wind capture sites and the annual sustainable harvest of wood. This subject occupies most of Section 3.4. Next, the potential availability of energy resources is matched by quality and scale to the energy requirements described in Section 3.3 above. Finally, an Energy Supply sector is created from among those sources and forms that are available and that meet soft path criteria for technical efficiency. The choice is made strictly according to existing or projected cost-effectiveness in the Business as Usual scenario and, in some cases and some provinces, on somewhat less stringent criteria in the Consumer Saturation scenario. Cost-effectiveness is of course determined by comparing the real marginal supply costs of conventional sources, as projected (Table 2.4), with the comparable costs of new sources (Section 2.4). New energy sources were phased in and old ones phased out as economic availabilities changed over time. Because technologies do not replace one another overnight, ample time was allowed to amortize old capital stocks and to establish new systems with appropriate consumer and environmental standards. Thus, even though in many provinces wood is already a cost-effective replacement for fossil fuels, the transition is assumed to last several decades. On the other hand, local introduction of new technologies before they were fully cost-effective was permitted to reflect both testing and the fact that a few users will want a slightly sub-economic technology for reasons of energy security or independence. For example, even though vegetable oil is unlikely to be a cost-effective substitute for diesel oil until after 2000, a 1% penetration rate in Saskatchewan's agricultural subsector was assumed for that year.

Stated as in the previous paragraph, the approach may appear to be more straightforward than it really is. The question at issue is what sources of energy are most appropriate to the levels of energy outlined in Section 3.3, with the word "appropriate" defined by soft path criteria. However, a major energy delivery capacity that meets few of those criteria already exists and cannot be ignored. Per contra, a major renewable energy supply system that does meet those criteria is only beginning to develop and needs time to prove itself. Moreover, political decisions have been taken and are still being taken

TABLE 3.9

PROVINCIAL USE AND SOURCES OF ENERGY

Province	1978	Business as Usual 2000	Business as Usual 2025	Consumer Saturation 2000	Consumer Saturation 2025
A. TOTAL SECONDARY ENERGY USE (1978 = 100)					
Newfoundland	100	102	87	72	59
Nova Scotia	100	115	90	86	73
Prince Edward Island	100	79	68	64	53
New Brunswick	100	130	115	98	82
Quebec	100	96	73	73	56
Ontario	100	106	92	79	68
Manitoba	100	86	66	66	50
Saskatchewan	100	91	79	71	61
Alberta	100	112	108	86	83
British Columbia	100	109	93	82	65
Yukon Territory	100	128	139	93	106
Northwest Territory	100	150	149	104	101
Canada	100	104	88	78	66
B. SHARE OF TOTAL SECONDARY USE FROM RENEWABLE SOURCES (%)					
Newfoundland	18	57	79	70	85
Nova Scotia	3	15	41	15	47
Prince Edward Island	7	34	50	36	99
New Brunswick	17	38	57	40	61
Quebec	23	51	87	53	88
Ontario	13	34	60	42	61
Manitoba	19	30	80	38	82
Saskatchewan	6	25	93	32	97
Alberta	2	41	93	49	100
British Columbia	37	71	93	71	93
Yukon Territory	15	46	85	62	92
Northwest Territory	8	32	67	48	80
Canada	16	33	77	45	82

C. SHARE OF TOTAL SECONDARY USE FROM INTRA-PROVINCIAL SOURCES (%)

Newfoundland	12	98	86	99	89
Nova Scotia	18	25	85	75	89
Prince Edward Island	11	28	34	33	87
New Brunswick	19	42	62	45	65
Quebec	18	53	93	54	94
Ontario	7	33	65	32	74
Manitoba	22	29	86	42	80
Saskatchewan	50	91	100	100	100
Alberta	100	97	97	100	100
British Columbia	59	97	86	100	86
Yukon Territory	19	21	21	23	26
Northwest Territory	34	32	44	63	33
Canada	87	96	96	97	96

that either pre-empt or constrain options that might be desirable on soft path grounds; neither can these be ignored. Finally, it is reasonable to assume that some major conventional resource projects (the "megaprojects") will go ahead if only because they are so politically visible. Thus, even though our study is demand-driven rather than supply-driven, and even though it aims for renewable and locally developed sources of supply, both realism and the need for a smooth transition indicate that the results will be mixed so far as soft path goals are concerned.

Changes in the Distribution of Energy Use by Form

An overview of the results to be discussed in this section can be obtained by looking at the projected changes in the physical and geographic distribution, of energy sources and forms. (While the focus in this part of the chapter is on primary sources, in many cases it is convenient to present the discussion in terms of the secondary forms used by the consumer.) The absolute and relative changes with time for the scenarios are shown in Figures CA-3 and CA-6 and summarized in Table 3.10.

As shown in the figures and table, use of coal and peat grows modestly in both scenarios. Coal grows less because it is used as a source of electricity (indeed, coal-fired electricity drops to about one half of 1978 levels by 2025) than because coal is needed for process heat in the steel industry and for steam to propel ocean-going ships. (Total use of coal, including coke used as a non-energy product, tends to be about 50% above the figure for secondary use alone.) Peat is used both

TABLE 3.10

PERCENTAGE DISTRIBUTION OF SECONDARY ENERGY BY FORM

		Business as Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Coal and Peat	2	6	8	5	8
Natural Gas	23	22	10	23	6
RPPs	54	23	3	21	2
Electricity	17	22	23	23	24
Biosolids	4	13	17	16	20
Biofluids	0	13	33	11	33
Active Solar	0	2	6	3	7

for heating and as an input to make liquid fuels for transportation. Refined petroleum products exhibit a steady decline, as would be expected given the limited resource base, from around half the supply mix in 1978 to less than one-quarter in 2000 and just a few percent in 2025. (Much larger quantities of RPPs -- 580 to 790 petajoules depending upon scenario -- continue to find uses as non-energy products.) The pattern for natural gas is different yet. For the first half of the projection period its share of the supply mix is constant, which means effectively no change in the level of production under Business as Usual conditions and a 20% decline under Consumer Saturation. However, between 2000 and 2025, usage falls off substantially so that it provides only 10% of supply in the Business as Usual scenario and 6% in the Consumer Saturation. As explained below, this reflects reduced demand for gas at the assumed price levels rather than resource limitations.

The supply of electricity exhibits still a fourth pattern. From about 17% of the supply mix in 1978, it grows to provide around 23% in both scenarios and both projection years. In absolute terms this means that electrical production would peak about the year 2000 and then decline slowly thereafter as total energy demand falls.

The share of energy supplied by renewable forms increases over the study period (Table 3.9). Ignoring hydro and other renewable sources of electricity, the share of renewable energy starts at 4% in 1978 entirely as biomass solids, mainly wood wastes used as fuel in the forest industries. The share grows to 56% by 2025 in the Business as Usual scenario and to 60% in the Consumer Saturation. Within that growth, the three categories fare quite differently. Active solar grows steadily as a fuel for Heating and Cooling and for Intermediate-Temperature Process Heat, but even in 2025 is only providing 6 or 7% of secondary use. Use of biomass solids increases between three and four times up to 2000, but little either absolutely or relatively thereafter. The largest change occurs with biomass fluids (mainly alcohol fuel but including some biogas), which start at nil, climb to supply more than a tenth of secondary use in 2000 and a third (both scenarios) in 2025. In absolute terms, of course, the growth is not so strong because total energy use is declining. Nevertheless, as shown by the way the increase in the use of biomass mirrors the decrease in the use of refined petroleum products in Figures CA-3 and CA-6, one of the principal results of the projections is the gradual substitution of renewable biomass for nonrenewable crude oil.

If the share of electricity supplied by renewable energy sources is included, the shift to renewables is even more marked. In 1978 about 68% of all electricity was produced from hydraulic sources. In both scenarios, as discussed with respect to specific sources below, the renewable share of electricity climbs: slightly to around 75% in 2000 and rapidly thereafter to over 90% in 2025. During the first period the increase is largely a result of the construction of new hydro capacity (most of it already under construction in 1978); after 2000 other renewable-based sources of electricity (wind, solar, wood) begin to contribute significantly.

When renewable-based electricity is added to other renewables, the total share of energy supplied by renewable sources in Canada grows from 15% in 1978 to 43% in 2000 and 77% in 2025 in the Business as Usual scenario, and to 46% in 2000 and 83% in 2025 in the Consumer Saturation scenario.

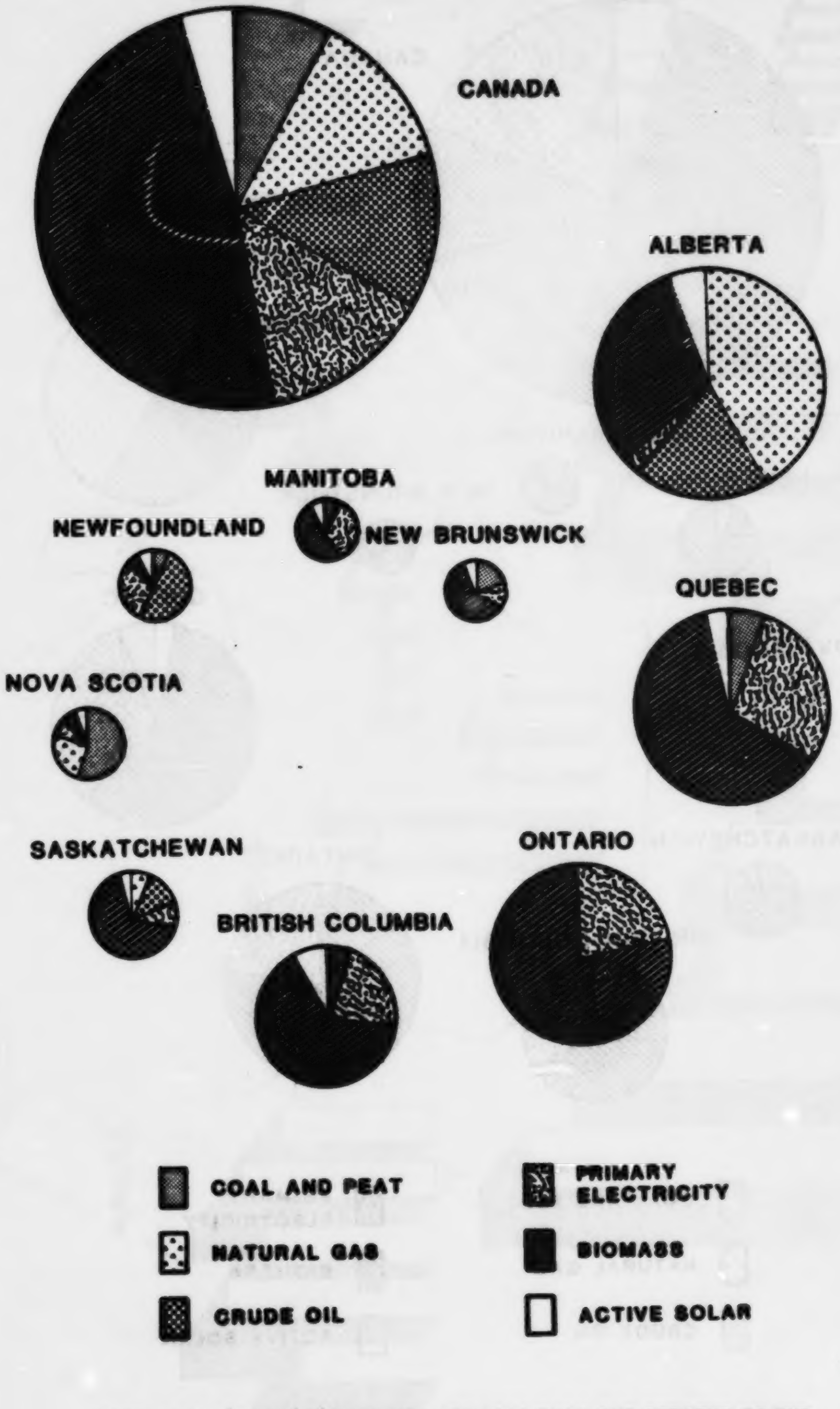
In summary, the patterns of supply developed here would move Canada toward the objectives of a soft path. Not only is the share of renewables increased relative to nonrenewables, which means greater sustainability, but the supply mix has become more diverse, which means greater resiliency. Moreover, as will be indicated in the next section, energy production is no longer so heavily concentrated geographically, but is more widely distributed among the provinces. Finally the transition is gradual. Even in 2000 renewable sources provide less than half of total supply. However, their production base is growing, and the year 2000 represents a transition toward an energy system dominated by renewable sources in 2025 and beyond.

Changes in the Production of Energy by Province

Changes in the forms of energy supplied are paralleled by changes in the distribution of energy production among the provinces. Provincial energy production by form for 2025 is shown in Figures 3.11 and 3.12, which should be compared with Figure 3.2 for 1978. Figure 3.13 shows the changes over time in domestic energy production for each province, relative to 1978 and to each other. The figures show that production of energy in either scenario would be much more evenly distributed under soft path projections than it is today. (In order that this comparison can reflect the soft path analysis of the study, Figures

FIGURE 3.11

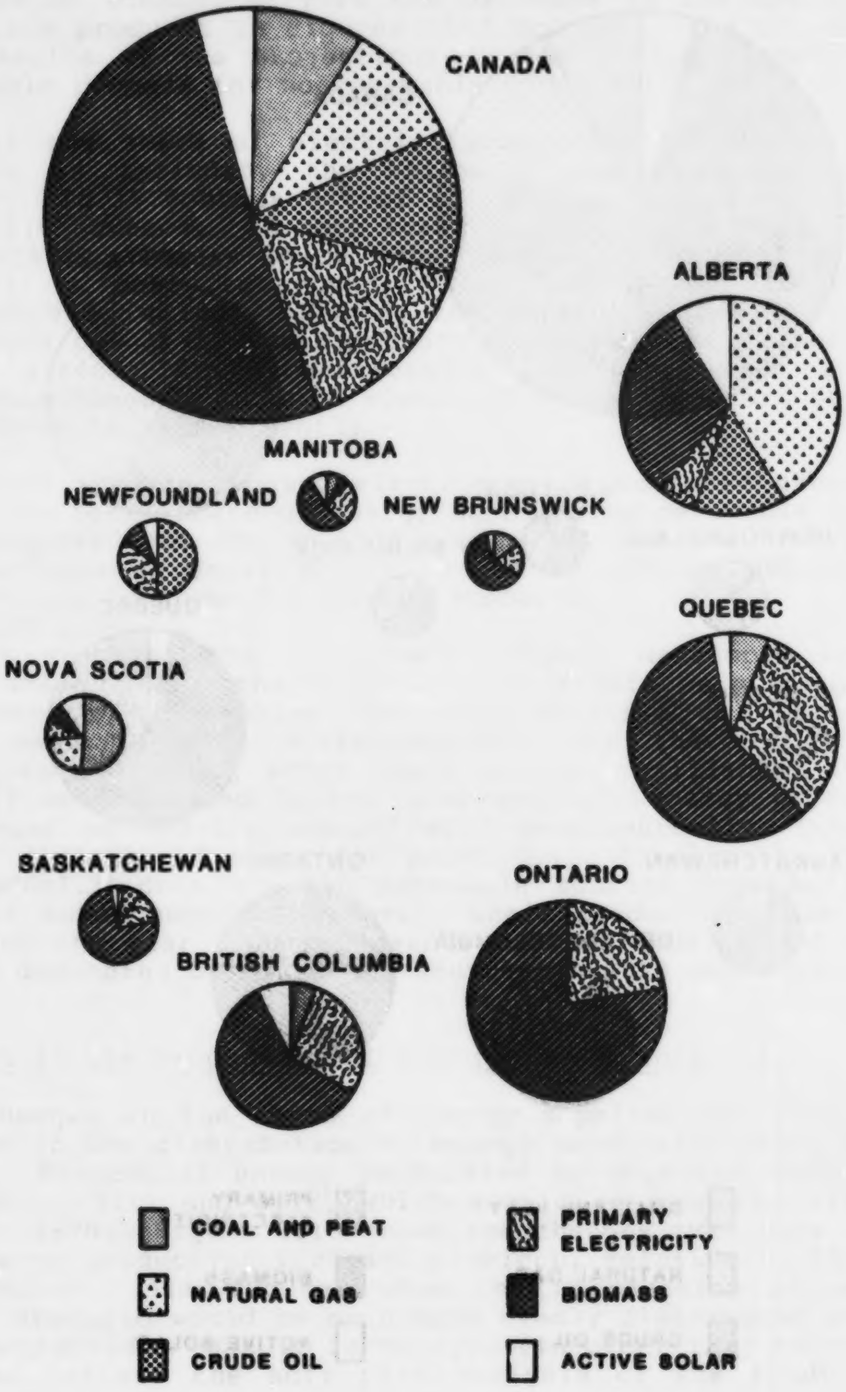
PROVINCIAL DISTRIBUTION OF PRIMARY ENERGY PRODUCTION FOR USE IN CANADA IN 2025, BUSINESS AS USUAL SCENARIO



NOTE: P.E.I. AND THE TERRITORIES ARE LESS THAN ONE PERCENT OF THE CANADIAN TOTAL

FIGURE 3.12

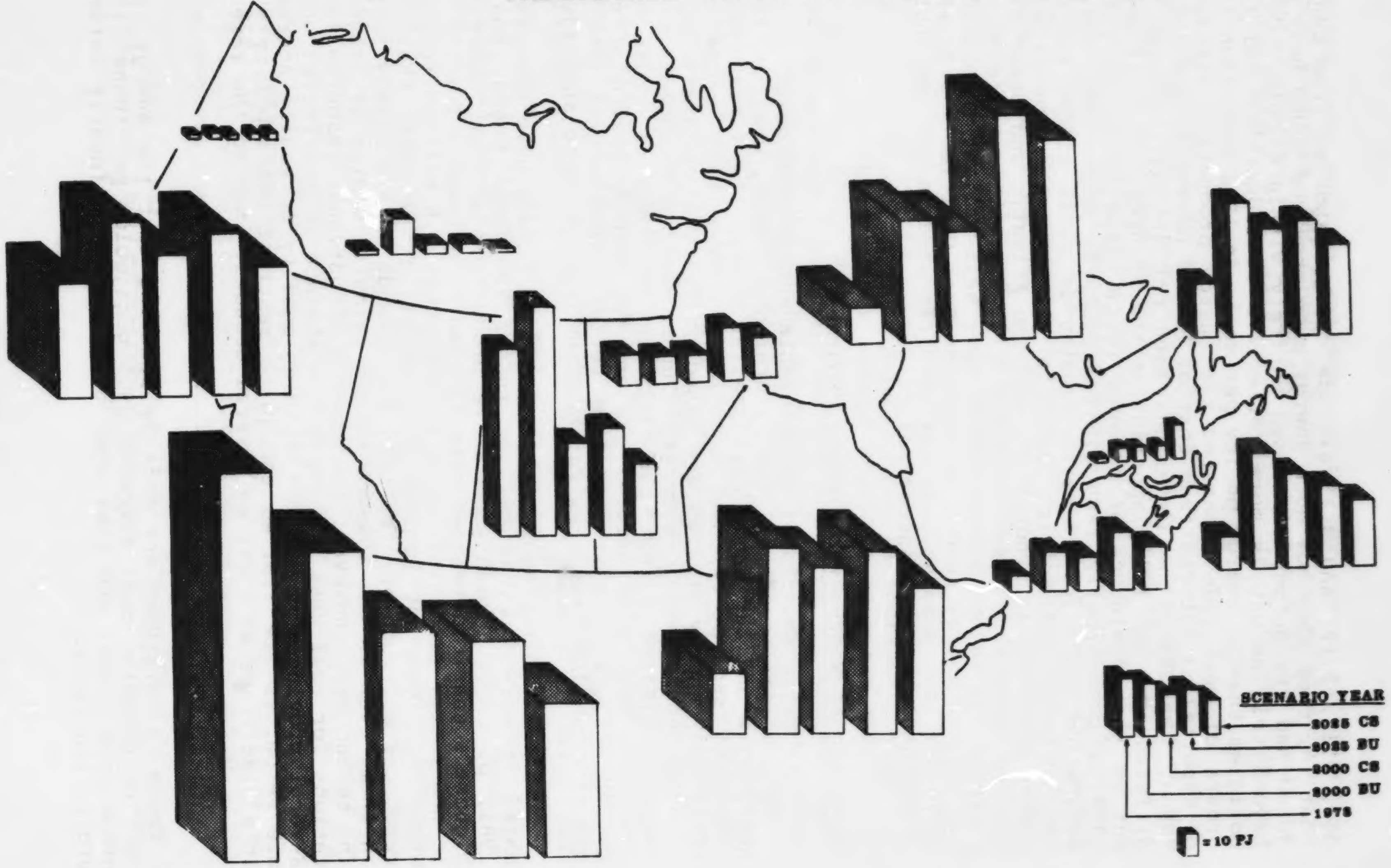
PROVINCIAL DISTRIBUTION OF PRIMARY ENERGY PRODUCTION FOR USE IN CANADA IN 2025, CONSUMER SATURATION SCENARIO



NOTE: P.E.I. AND THE TERRITORIES ARE LESS THAN ONE PERCENT OF THE CANADIAN TOTAL

FIGURE 3.13

REGIONAL PRIMARY ENERGY PRODUCTION



3.2, 3.11, 3.12, and 3.13 exclude energy exported from Canada; that is, they show how much energy each province would have produced had its output been used entirely within Canada. Output beyond this amount is more reflective of industrial and trade policies than of energy policy per se.) In 1978 more than three orders of magnitude separated the energy production (exclusive of exports) of Alberta from that of Prince Edward Island and the Yukon. By 2025, the ratio has been cut in half, though this difference is not fully apparent on the figures. What is apparent is that dominance of Alberta in Canadian energy output in 1978 is dramatically reduced, particularly under the Consumer Saturation scenario. Alberta remains in first place, but Quebec, Ontario and British Columbia all come to provide major shares of Canadian production, and the Atlantic and other Prairie provinces have also increased their shares. In effect, each province has become substantially more self-reliant in providing for its own energy needs, as shown on Part C of Table 3.9, which indicates that some success has been realized in meeting another of the goals of soft energy policies.

Conventional Nonrenewable Energy Sources

The major sources of nonrenewable energy considered in this study are coal, crude oil and natural gas. Peat, uranium, LPGs, heavy oils and tar sands play smaller roles; the first two are discussed separately, and the latter three with crude oil. While many energy studies are based on fears of ultimate depletion of nonrenewable sources, Canada does not appear to be resource limited except partially in the case of crude oil. The shift away from natural gas and the modest growth of coal use in the projections stem from better opportunities with the use of renewable resources rather than from resource shortages.

Mineable bituminous coal reserves in Canada have been estimated at more than 16 billion tonnes (National Energy Board, 1981, p. 191). Total cumulative production of coal under the highest scenario developed here (including allowance for its use in non-energy products) would be less than 1.5 billion tonnes.[2] While this does not include net imports, it is clear that coal resources are much greater than the demands we are likely to put on them, even in the absence of any gains in mining or processing technology. However, the absence of national resource limitations for coal does not imply the absence of provincial ones. Several provinces may find that high-quality or easily accessible resources are limited enough to restrict availability even in a time frame as short as several decades. Nor do the reserve estimates take much if any account of environmental criteria. The coal reserves that could be mined without unacceptable environmental disruption are smaller, but they are still likely to be much larger than domestic requirements through 2025 and beyond.

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[2] These calculations are made by assuming that the energy content of Canadian coal averages 29.3 gigajoules per tonne (i.e. bituminous grade) and that coal usage changes linearly between projection years.

Coal plays a role in almost every province, but in most cases it is a small one. Absolute usage increases by more two times in the Business as Usual scenario (less than two times in Consumer Saturation), but in no province does coal provide as much as 15% of total secondary supply. Although coal is a reasonably dense fuel, additional usage is restricted partly because it is too costly for many uses compared with alternatives and partly because its use involves both immediate (particulates, acid rain) and long-term (carbon dioxide) problems to a greater extent than do other fuels.

Including its non-energy use as a reductant in metallurgy (a process which gives off heat), there are three major ways in which coal is used in the projections. In increasing order of importance these are: as a source of steam in a new generation of ocean-going ships and coastal ferries (5% of coal use), in electrical generation (35%) and as a source of process heat (60%). Steam-powered ships represent a small but growing use, whereas use in electrical generation stays roughly constant through 2000 but is gradually replaced thereafter by cleaner sources of electricity. A little new capacity is constructed between 1978 and 2000, mainly in relatively small fluidized-bed plants. However, except in New Brunswick and Nova Scotia, almost all coal-fired electrical generation is replaced by cheaper alternatives by 2025. The major continuing use of coal is as a source of process heat, particularly high-temperature heat. (At the start coal is the source of about 22% of the high-temperature heat; by 2025 it is the source of 35%.) Of course, some of this heat may also be used to cogenerate electricity, but this would show in the approach used here as a reduction of electricity demand rather than as an increase in supply.

Major coal deposits in Canada are found in Nova Scotia, Saskatchewan, Alberta and British Columbia. (Coal production is quickly phased out in provinces such as New Brunswick with poor quality deposits.) Because qualities vary (some coals cannot be made into coke and some are more polluting than others) and transportation costs are high, balancing supply and demand through interprovincial trade alone is not feasible. Hence, exports (from the West) and imports (to Ontario) continue at fairly high levels throughout the study period. Much of this trade involves coking coal.

Turning to natural gas, the National Energy Board (1981, p. 152) estimated that recoverable reserves in 1980 from conventional resoures (i.e., excluding offshore or Arctic gas) amounted to just under 2.0 trillion cubic metres. Cumulative production in the highest scenario would be about 1.4 trillion cubic metres.[3] Exports are large and would add to the drawdown of reserves. However, in contrast to oil, new discoveries of gas have been keeping pace with pumping in recent years, so there is every reason to expect the reserve figure to remain stable or even grow. In its report released in September 1980, the Geological Survey of Canada expects another 400 million cubic metres in western Canada and 1 trillion cubic metres in total to be discovered in the decade of the 1980s alone (50% probability level in each case). As with coal, use rates as projected here will not push seriously against resource limits for natural gas.

The situation is different for crude oil. Remaining conventional reserves were estimated to be only 745 million cubic metres at the end of 1980 (National Energy Board, 1981, p. 117). In the Business as Usual scenario cumulative use of crude oil through 2025 would be almost 2,000 million cubic metres,[4] primarily as a feedstock for the petrochemical sector, and there is little hope that conventional reserves could grow to supply this volume. Of course, the projections here assume that oil will also be produced from tar sands and heavy oils and from offshore fields. Billions of cubic metres of synthetic crude may be recoverable from the tar sands and heavy oils of Alberta and Saskatchewan and 1 to 2 billion cubic metres of recoverable crude may lie in fields off the east coast of Canada (National Energy Board, 1981, p. 141). With these additional supplies there should be no trouble finding oil to supply the petroleum products used in our scenarios. In summary, when dealing only with reserves of conventional crude, Canada appears to be resource limited; if the reserve picture extends to nonconventional and frontier resources, we are not and, as with coal and natural gas, economic limitations and environmental limitations come to play the greater role.

Over the course of the projection period, total oil use declines from satisfying half of Canada's secondary energy requirements to just a couple of percentage points (excluding non-energy products; see Section 3.5). Even by the year 2000, petroleum products have been replaced in most provinces as sources of low- and mid-temperature heating and in electrical generation and are used largely either as Liquid Fuel in transportation, agriculture and construction or as a source of

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[3] This calculation is made by assuming that the energy content of western natural gas is 37.4 gigajoules per thousand cubic metres and that natural gas usage changes linearly between projection years.

[4] These calculations are made by assuming that the energy content of crude oil is 38.4 gigajoules per cubic metre and that crude oil use changes linearly between projection years.

High-Temperature Process Heat. RPPs can be totally replaced by 2000 under Consumer Saturation conditions in provinces such as British Columbia with abundant and low-cost biomass. Nevertheless, conventional oil reserves, even with expected additions to known fields, are unlikely to be able to provide for this level of demand. Although there are of course alternative renewable sources to fill the demands now supplied by refined petroleum products, none could (or should) grow in use rapidly enough to alter this situation measurably. Furthermore, recourse to increasing imports is politically unacceptable for security reasons and methodologically unacceptable because it merely shifts the burden of finding soft sources elsewhere. Therefore, the conclusion that additional supplies of oil must be found seems inescapable. In order to furnish the levels of demand for RPPs projected in this study, two large-scale oil projects need to be developed between now and 2000 (which is the point at which the gap between conventional oil supply and projected demand for Liquid Fuel is the greatest). This is well within the country's capabilities and, of course, much below the levels of effort for oil development that are being contemplated at this time.

For the purposes of this study, the two oil megaprojects that were brought into production include one further oil sands (or heavy oil) plant and one field off Newfoundland. The synfuels plant would produce 280 PJ per year (140,000 barrels per day at 90% capacity); existing synfuels plants are expected to continue in production at capacity. The offshore field would produce 140 to 160 PJ per year (around 70,000 barrels per day); continuity in production at this level is maintained by developing offshore fields sequentially (which is consistent with the current policy of the Newfoundland government). Of course, existing conventional reserves together with additions to known fields and modest discoveries are also produced and eventually exhausted.

As a result of these supply projections, Alberta continues in its role as the main supplier of oil (and natural gas; see below) for Canada, with Newfoundland as a major secondary source (a role Nova Scotia fills in the case of natural gas). Under these projections, plus a declining total use of RPPs, Canada quickly becomes self-sufficient in crude oil and oil products. Indeed, there will be excess production capability in the crude oil industry after 2000 under Business as Usual conditions (and before that under Consumer Saturation), as discussed again in Section 3.6. Oil movements within Canada shift somewhat from crude to refined products as oil refineries expand in the West. However, Newfoundland is assumed to ship 60 to 75% of its production in the form of crude as construction of additional refining capacity on the Island is deemed unlikely.

Conventional reserves of natural gas, including proven reserves and unexpected additions and discoveries, are so large that there is no need to bring in additional supplies. However, for a variety of reasons it is likely that at least one field in the East, presumably Sable Island, will be in production before 2000, and this has been built into our projections at a capacity of 115 PJ per Year (300 million cubic feet per day). The completion of the Trans Quebec and Maritimes pipeline to Halifax is also assumed. However, no extension of the pipeline to PEI is included; straightforward calculations show that the cost of gas delivered by underwater pipeline would be well above that for local biomass. Nor is any gas assumed to be landed in Newfoundland from offshore fields because of the absence of any clear resolution of the economics of delivery.

The main sources of natural gas in the projections are Alberta and Nova Scotia, with Alberta being by far the larger. British Columbia and Saskatchewan remain essentially self-sufficient in gas, and minor amounts are produced in other provinces. Major movements of gas eastward continue through 2025, though at diminishing rates. This movement is large enough that the energy required for pumping is significant, particularly in Saskatchewan and Manitoba, through which almost all of this gas must pass. Moreover, the continued export of natural gas is assumed, though no specific levels for exports are projected.

Extension of pipeline service to all provinces but Newfoundland and Prince Edward Island makes natural gas the transition fuel par excellence in most of the country. With its clean, intense heat, it can serve as a bridge between today's largely hard mix of energy sources and the soft mix projected here. Partly for reasons of supply availability and partly because of its characteristics, the use pattern for natural gas is different in the projections from that of any other fuel. For the first half of the study period, use grows marginally in the Business as Usual scenario and falls slightly in the Consumer Saturation. This reflects the continuation of past uses (most of the buildings now using gas for space and water heating will continue to do so), and a high rate of replacement for oil heating (both space heat in buildings and process heat in industry) and for some oil-fired electrical generation in areas newly served by gas. As well, in a few provinces (British Columbia, Nova Scotia) compressed natural gas (CNG) replaces some of the gasoline used to drive urban vehicles, and in Alberta natural gas is used as a source for methanol. (The economics of this last conversion are questionable at the price levels assumed here, but the plants already exist or are being built, and they can serve as a bridge to biomass-derived methanol.) After 2000, however, as natural gas prices continue to increase and total secondary energy use begins to drop, the use of natural gas falls off substantially -- by nearly 40% in the Business as Usual scenario and by more than 75% in the Consumer Saturation. Very few new buildings of any type are connected to natural gas lines after 1990 as their low level of energy use for space and water heating cannot pay back the costs of connection. Electrical generation using gas is economic only during a window centering on about 2000 (New Brunswick's gas-fired capacity goes from nil in 1978 to as much as 670 MW in 2000 and then back to nil in 2025), and use of gas for process heat is replaced by biomass solids and direct solar. Typical is the pattern of use in Quebec; natural gas accounts for only 7% of secondary supply in 1978, but grows to 21% in 2000, and then falls back to 4% in 2025. In effect, natural gas' role as a transition fuel is ending as the study period ends. However, there are wide differences among the provinces in the extent to which natural gas is still in use in 2025. In some, including Alberta (which has low-cost biomass as well as low-cost oil and gas), usage is completely eliminated by 2025, while in others, such as Ontario (which has fewer alternatives), it still provides as much as one-fifth of the supply.

One further nonrenewable resource plays a minor role in the study: uranium. Nuclear generating stations produce electricity in Ontario, Quebec and New Brunswick. Only those in Ontario are in operation in 1978, but all play some role in the year 2000. (Only in Ontario is that role very large.) Given the thrust to develop a soft supply mix, it has been assumed that any nuclear station existing or irreversibly under construction in 1978 would operate for its expected lifetime but that no further plants would be commissioned. Therefore, uranium is completely eliminated as a supply source sometime between 2000 and 2025.

New Nonrenewable Energy Sources

The final nonrenewable energy source that plays a significant role in this study is a nonconventional one in Canada (though not elsewhere): peat. In principle, peat deposits are renewable but over time frames measured in thousands of years. The projections show peat being used as an energy source in Newfoundland, New Brunswick, Quebec and Manitoba. National production by scenario and year is shown in Table 3.11. There is no trade in peat for energy purposes because its density is so low that it cannot economically be transported very far. Projected harvest rates go as high as 9 million tonnes, yielding 90 PJ per year (in Quebec; much less elsewhere), but with reserves measured in the billions of tonnes, such levels of production seem physically acceptable. No conflict should arise between "energy peat" and "agricultural peat" because there are quality differences between the two (though the reserve measurements are not good enough to indicate how much of each quality exists). However, care will be needed to mitigate the environmental impacts of extensive peat harvesting, including the reclamation of spent peat bogs. One opportunity, described at greater length below, is to use spent bogs to grow high-yield trees in energy plantations. So far as combustion goes, peat is far less polluting than any of the fossil fuels provided that particulate control is maintained. Ultimately of course peat remains nonrenewable, so it is best seen as a transitional fuel.

TABLE 3.11

PRODUCTION AND USE OF PEAT FOR ENERGY IN CANADA BY YEAR AND SCENARIO
(Petajoules)

Scenario and Year	PRIMARY SOURCES Production	PRIMARY SOURCES Availability	PRIMARY SOURCES Energy Supply Sector	SECONDARY FORMS Production	SECONDARY FORMS Energy Supply Sector	SECONDARY FORMS Use	SECONDARY FORMS Form
1978	-	-	-	-	-	-	-
BU 2000	75.7	23.7	2.7	21.0	-	21.0	Heat
		30.0	20.1	9.9	1.0*	8.9	Electricity
		22.0	9.0	13.0	-	13.0	Methanol
BU 2025	121.3	32.8	2.7	30.1	-	30.1	Heat
		22.5	15.2	7.3	0.7*	6.6	Electricity
		66.0	23.0	43.0	9.0	34.0	Methanol
CS 2000	33.3	10.9	3.9	7.0	-	7.0	Heat
		2.4	1.6	0.8	0.1*	0.7	Electricity
		20.0	7.0	13.0	3.0	10.0	Methanol
CS 2025	83.2	23.4	3.4	20.0	-	20.0	Heat
		4.3	6.7	2.6	0.3*	2.3	Electricity
		50.0	17.0	33.0	7.0	26.0	Methanol

NOTES: 1. This table follows the format of Tables CA-2 and CA-12 through 15 except for the elimination of the two columns for international trade, which is nil for peat, and the one for non-energy products (agricultural peat is excluded from the primary production column).

2. BU - Business as Usual Scenario; CS - Consumer Saturation Scenario

* 10% loss assumed

Except in Quebec, the major uses of peat in this study are for direct heating and as a source of electricity (to replace oil- and to a smaller extent coal-fired capacity). The technology for peat-fired electricity is already widely used in Finland, Ireland and the USSR. Newfoundland projects the construction of four 120 MW plants by 2000 and New Brunswick the construction of one 40 MW plant by 2000. In these provinces and in Manitoba, peat would also be used for residential and commercial heating and for industrial process heat in areas close to peat bogs, but such uses never total to more than a few petajoules per year. In Quebec, peat is not needed as a source of electricity, so much of the production is used as industrial process heat. However, by 2025 50 to 65 PJ per year are used as a feedstock for methanol production (Table 3.11) and provide almost one-tenth of the Liquid Fuel needed in that province.

Conventional Renewable Energy Sources

Only hydroelectricity is treated as a conventional renewable energy source for the purposes of this study. While it is ironic for wood to be called a "new" source, the projected scale and techniques of production are sufficiently different from those of the past as to justify that classification.

Some 69% of Canada's electricity was generated from hydropower in 1978. By the end of the study period, the share grows to 93% under Business as Usual conditions and to 95% under Consumer Saturation. Hydropower is an important source of electricity in every province except Nova Scotia and Prince Edward Island. Even in PEI it plays an indirect role (via the underwater cable from the mainland), and in Nova Scotia the smallest of the proposed sites for tidal power on the Bay of Fundy is assumed to be providing about 50% of the electricity requirements by 2000. In some provinces hydropower is overwhelmingly predominant. This situation does not change in this study; indeed if anything, reliance on hydropower is increased with the construction of a few major projects and a considerable number of small-scale or mini-hydro schemes. This level of development is quite within the physical potential for hydropower in all provinces where it is important. Well before physical limits are reached, both economic and environmental ones come into play, something that can best be seen by reviewing expected hydropower developments as projected by the provincial studies.

Newfoundland's hydropower situation is complicated by the fact that the major potential occurs on the mainland (Labrador) whereas the major markets occur on the island. Even with conversion of ore drying in the iron mining industry from bunker oil to electricity, total demand in Labrador in 2000 would not exceed 12 PJ (300 MW at 60% capacity) compared with about 47 PJ in Newfoundland. Thus, an infeed to the island is generally accepted as necessary prior to 2000; in both scenarios, this infeed is assumed to be 800 MW. The Gull Island (Lower Churchill) site might or might not have to be developed depending upon how much of the energy from the existing Upper Churchill project (over 4000 MW) could be recaptured for use within Newfoundland and Labrador. Delivered costs on the island would be high--perhaps $0.07 per kW.h--but this appears likely to be competitive with oil-fired generation. Finally, in Newfoundland, as in most other provinces, existing hydro plants and the infeed could be supplemented by a number of small-scale hydro developments where local conditions warrant.

New Brunswick has identified an undeveloped hydropower potential (from rivers with drainage areas greater than 275 square km) of 2500 MW (Province of New Brunswick, 1980). Tidal projects were excluded as too costly and too dangerous environmentally. Existing hydro capacity is just over 800 MW. Only a marginal increase is needed to satisfy demands in the year 2000, but just under a doubling of this capacity would be required between 2000 and 2025 as nuclear and gas-fired plants are phased out. (A small part of this capacity would be used for a second cable to PEI.) It seems likely that the additional 720 MW can be found from sites that would not be overly destructive of environmental values.

Quebec is one of three provinces where hydropower is predominant. In 1978 the capacity of hydro plants was almost 17.4 GW (about 4 of which came from Churchill Falls in Labrador); production was 356 PJ, including 107 from Labrador. The addition of Phase 1 of the Baie James project and the additional generators at Manic 5 will push hydro capacity to more than 28 GW. (Quebec also has some fossil-fuel-fired peaking plants and off-grid diesel plants, and one nuclear plant will come into operation in the 1980s.) This capacity is sufficient to provide for all foreseeable needs throughout the study period, even assuming that Newfoundland recaptures some Upper Churchill power and allowing for continued electrification of the Quebec economy (e.g., electric vehicles in cities). A surplus in the hundreds of petajoules is available for sale to Ontario (which needs power to replace its existing nuclear plants by 2025) and to the United States. An additional potential of some 10 GW has been identified at small-scale sites, some of which have been assumed to be developed by the year 2000 to replace aging plants elsewhere in the system and to improve the load factor through system optimization.

In Ontario, hydroelectric supply increases by 9 PJ by 2000, and by 2025 reaches 170 PJ, only 29 PJ above its 1978 level. This implies a much more modest program than the current official target of an additional 2000 MW of hydrocapacity (equivalent to 30 PJ at 50% capacity factor) by the year 2000.

Manitoba and British Columbia are the other two provinces (besides Quebec) where hydropower today dominates electrical generation. Manitoba produced about 65 petajoules per year in 1978 of which 11 PJ were sold to other provinces or to the United States. Including Revelstoke (on stream in 1984), British Columbia can produce nearly 200 PJ per year even during low water years, of which at least 10% is surplus to its needs. However, in both provinces the additional potential is located at sites that are both more costly and located in environmentally and socially sensitive northern areas, whereas the major markets lie in the south. Although the provincial crown corporations in both provinces have vast expansion plans, the scenarios developed here show that, just as in Quebec, no further expansion (apart from replacement plants) is required through the year 2025, even if major electricity-intensive industries are assumed to locate within the provinces. In Manitoba some curtailment of exports would be required under Business as Usual conditions in 2000, but other exports and interprovincial sales (notably from B.C. to Alberta in the Business as Usual Scenario) could continue.

Electrical generation in Alberta and Saskatchewan is currently dominated by coal-fired stations, but each has considerable hydro-electrical potential. As elsewhere much of that potential occurs in socially and environmentally sensitive areas. Saskatchewan found sufficient hydropower through full development of the Saskatchewan River (29 PJ per year) and excluded any development in the north. Alberta has an "established" potential of just over 100 PJ per year of hydropower, which includes the existing 6 PJ but excludes another 100 PJ of the "total developable" power. The scenarios project the need for development of about 80% of the "established potential". This target could be met by any of a number of plans. For example, if the Peace River was fully developed, no other river system would have to be touched; alternatively, identified sites in the Athabaska and the North Saskatchewan basins could be developed with all other rivers (apart from existing sites) left untouched.

For both the Northwest and Yukon Territories, electricity requirements peak in 2000 in the Business as Usual scenario at about twice 1978 levels, based on an analysis of each subsector. Even allowing for the substitution of hydro for thermal generation, the need for additional hydro capacity in each Territory is limited to approximately 50 MW, which can easily be found either at single sites or, more likely, at several smaller installations located close to load centres.

In sum, while additional hydroelectric developments are seen as necessary in some provinces in the scenarios in this study, and while none of the developments is free of adverse environmental and social impacts, the level of hydro developments needed is well within resource limits and avoids any development at highly contentious sites.

New Renewable Energy Sources

Three general renewable sources of energy are used in this study: active solar heating and electricity, biomass solids and biomass fluids. (Passive solar heating is treated as a conservation technique, hence included in Section 3.3 on demand.) Of these three, active solar is by far the smallest component; biomass solids form a small part of our energy supply today, grow quickly to the year 2000 but not much thereafter; and biomass fluids provide only a little energy in 2000 but a large share in 2025. The three sources will be discussed in that order.

Resource limitations are not directly relevant for the capture of solar energy. Enormous amounts of energy from the sun reach the earth daily. For example, strictly in terms of energy availability, Alberta's maximum annual energy use could be provided by a set of solar collectors that are 50% efficient and measure 20 km on a side. Needless to say, economic limits come to dominate at much lower levels of production.

According to the projections prepared for this study, active solar collectors become cost effective shortly before 2000 and very cost effective by 2025, at least if energy use is high enough. The qualification is a major one. By that same time, space heating requirements for buildings and low-temperature process heat requirements for industry are so low that it is unlikely that any capital-intensive system could repay its costs of production and installation. Hence, active solar heating finds its major use where demand is more stable over the course of a year, as with residential and commercial water heating, or larger, as with Mid-Temperature Process Heat. The projected costs of active solar heating in the year 2000 can be summarized from Chapter 2 as follows (in 1980 dollars):

Heating Below 100^{0}C	2000
Without Storage	\$9/GJ
With Seasonal Storage	\$16/GJ
Process Heat above 100^{0}C	
Without Storage	\$13.50/GJ

These costs, which are one-third to one-half of those prevailing today, do not drop further between 2000 and 2025. Thus, active solar heating starts to penetrate the market to supply Heating and Cooling energy in 2000 and somewhat later the larger market for Intermediate-Temperature Process Heat. Once the cost of solar heat (without storage) becomes less than the cost of conventional fuels, the transition in new construction should be short. Retrofits using solar will occur more slowly with electric water heating being replaced first. In rural areas seasonal solar systems could play a greater role; a simple coil in a wood-heated hot water system (which costs only about $150 installed) could supply requirements from November to May with the solar system operating during summer months.

Typical capture rates for active solar heating in the residential sector (mainly in single family detached dwellings) can be shown by figures from Saskatchewan projecting the proportion of space and water heating supplied by active solar systems in 2025:

	Business as Usual		Consumer Saturation	
	Space	Water	Space	Water
Pre-1990 stock retrofitted	--	20%	5%	50%
Post-1990 stock as built	5%	60%	5%	60%

Such systems would be expected to provide essentially all requirements by that date, though the earlier systems would provide only 30% to 70% of annual requirements and be backed up with conventional or biomass fuels. As indicated by the results for Saskatchewan, solar space heating remains almost negligible. Nationally, active solar heating provides 5 to 7% of the energy used in the Residential and Commercial sectors in 2000, and a little more than twice as great a share in 2025. Such shares are highest in the Western provinces, which have a relatively good winter sun regime and a lot of new construction, and least in the Maritimes, which have neither. For example, in Prince Edward Island, 4000 domestic solar hot water systems are expected to be in operation by 2000 and 20 000 by 2025; their contribution in the latter year will be only 7% of residential energy use. In British Columbia active solar is expected to predominate by 2025 with 46% of space and 60% of water heating. But even this volume of heating might be replaced by the capture of waste heat from photovoltaic electricity if this comes to be used.

Active solar penetration in the market for industrial process heat is very mixed from province to province. Nationally, between 1 and 2% of industrial heat (all temperatures, including Heating and Cooling) is provided by active solar in 2000 and 6 to 7% in 2025. Many provinces do not expect to use any active solar in the industrial sector. At the other extreme, Alberta finds that 10% of its process heat requirements can be met by solar in 2000 and about half by 2025. Despite the relatively small share for active solar in process heating compared with Heating and Cooling, the former is so much larger a total market that, in absolute terms, roughly equal amounts of energy go to the two markets in both scenarios.

Solar energy is also used to produce electricity by direct impact (photovoltaic devices) and by wind machines. As indicated in Chapter 2, system considerations limit the contribution of either to 15% (and the sum of the two to 20%) of the total electrical supply in any province. The costs of photovoltaics and wind machines (see Chapter 2) are such that they do not become cost effective against other sources until just before the year 2000, except at off-grid sites where inefficient diesel generators are used. (These costs were projected to be $19 per GJ for photovoltaic electricity and $15 per GJ for wind electricity in 2000 and 2025.) As a result of these considerations, the use of direct solar and wind in the scenarios is much below their availability.

Nationally, growth in the use of photovoltaic devices and of wind machines as sources of electricity is very slow. Essentially nil in 1978, neither amounts to as much as 0.5% of electrical generation in 2000. By 2025 wind and solar photovoltaics each account for 2% in the Business as Usual scenario and for 2% and 1%, respectively, in Consumer Saturation.

Provinces vary widely in the extent to which either form of solar electricity was tapped. Some have none, though typically, as in British Columbia and Quebec, this is more because of a surplus of electricity from existing hydro sites than from lack of cost-effective opportunities. Quebec makes an exception for wind at off-grid sites, particularly given the opportunity for some large scale machines (2 to 4 MW) but does not expect total capacity to climb beyond 60 MW (1.2 PJ per year), or less than 1% of electrical output. Newfoundland expects almost the same output from wind electricity, but in that province the machines would be located in a wind farm and connected to the grid--and they would provide nearly 2% of the electrical supply. This level of output is typical. In most provinces, wind machines and photovoltaics together are still nil or provide a percent or so of electrical requirements in 2000, and grow to provide two or three times as much in 2025. However, Prince Edward Island found that, at projected cost levels, wind could provide between 0.3 and 0.4 PJ per year, or 10% of peak loads, in 2000 and reach the limit of 15% of peak load by 2025. In New Brunswick and Saskatchewan (plus Alberta in the Business as Usual scenario), wind machines and photovoltaics were used to the limit of 20% of electrical supply in 2025.

The major renewable source of energy for Canada, according to the results of this study, will be biomass. Primary biomass sources are varied, as are the specific secondary forms, but for statistical purposes, the latter can be divided into biomass solids and biomass fluids. (The latter includes both liquids and gases, but the volume of biogas is much smaller than that of either bioliquids or biosolids.) To a considerable degree biomass sources replace fossil fuel, mainly petroleum, sources of energy, as shown in Table 3.12.

TABLE 3.12

PROJECTED SECONDARY USE OF BIOMASS VERSUS REFINED PETROLEUM PRODUCTS

		Business as Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Refined petroleum products	3242	1412	172	971	82
Biomass	211	1618	2662	1233	2070
Total	3453	3030	2834	2204	2152

Thus, within a total for energy use that is falling by one-fifth to two-fifths, the shares contributed by oil and by biomass almost reverse over the 47 years of projection. Their roles are also likely to be reversing. While today crude oil is predominantly an energy source with minor non-energy uses, and wood is predominantly a non-energy product with minor energy uses, by 2025 it is possible that oil will be seen mainly as a non-energy product with minor energy uses and wood will be predominantly an energy source with lumber and pulp and paper treated as non-energy products.

In looking further at biomass potential it is useful to list first the major sources, forms and uses of biomass, and also to introduce some of the questions raised by a shift to extensive reliance on biomass. (Environmental and land use concerns are discussed in Chapter 4.) This discussion will be followed by more detailed discussion organized around the various sources and uses of biomass and by a province-by-province review. The latter is included because of the wide variation among provinces with regard to their potential production of, and potential need for, biomass.

The sources of biomass can be broken down into two general types, those grown deliberately as an energy source and those which originate as a waste product of other activities. In this study the former include mainly fast growing trees used as a source for methanol and oil seed crops (such as rapeseed, called canola once it has been refined) used as a diesel substitute. The trees may be grown in energy plantations, in managed forests or in woodlots, or they may be found in less desirable stands or second-growth forests. A variety of other possibilities exist including the cultivation of grains or sugar crops as sources for alcohol or of one of the hundreds of species of trees and plants that produce latex or other hydrocarbons naturally (B. Felske, personal communication, 1982). The former were excluded for two reasons: to avoid any conflict with food production and because recent studies question the economics of production (Sanderson, 1981). The latter were excluded because too little is yet known about the economics of production, even for those latex-producers such as milkweed that can be grown in Canada.

In comparison with the few sources of biomass grown directly for energy, the number of sources that originate as plant or animal wastes is great. Most important so far as this study goes are the following: biomass left in the forest after harvesting (logging residues); biomass wastes at saw mills, paper mills etc. (mill residues); crop wastes including straw; miscellaneous organic industrial wastes; animal manure mainly from animals in feedlots; human sewage; and municipal solid wastes. Of these, the first several are the most important. At the start of the study period,, wastes predominate over biomass grown for its energy content, but the latter are dominant by the end. Throughout, forest biomass greatly predominates over agricultural biomass. Figure 3.14 illustrates this shift in the sources of biomass production over the study period.

The secondary forms in which biomass can be used by the final consumer are equally as varied as the primary sources from which it can be derived. They divide into three groups. First, some biomass is used directly as an input, as when logs are fed into a wood stove or industrial wastes consumed directly as in-plant sources of heat or electricity (or both). Second, the biomass can be processed to provide a better physical product for the consumer. Examples include the refining of vegetable oil to remove carbon-forming components and the production of wood chips or pellets from logs. (Either chips or pellets are easier than to handle in automatic feed equipment than are logs, but chips are still bulky and thus acceptable only for large or rural consumers with adequate storage space. Pellets are densified wood, which permits a reduction of two-thirds in volume, so they are much more attractive for urban consumers.) And, third, some energy forms are derived from biomass after substantial chemical or biological processing, as with the production of methanol or methane (biogas).

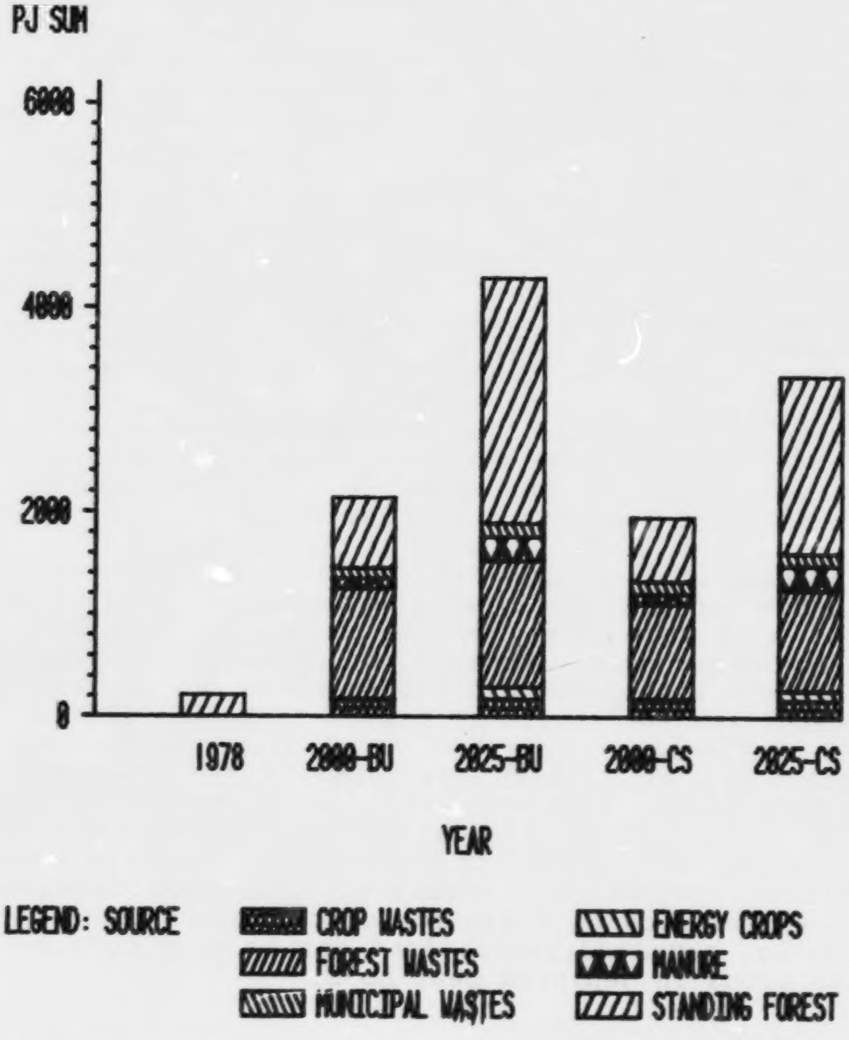
Table 3.13 shows the amounts and uses of energy derived from forest biomass. Note that in this table the distinction between that biomass collected as a residue and that harvested as a main product is based on land use. Only those forms of biomass that required no additional land use were treated as residues. Biomass obtained from so-called weed species or from forests affected by fire, disease or earlier logging is treated as a new harvest.

Biomass plays a role in filling the requirements for each of the four energy qualities. By 2025 about 20% of Heating and Cooling energy is supplied by biomass solids in various forms with another 5 to 10% supplied by biogas in local situations. By 2025 around 45% of process heat is supplied by biosolids and another 5 to 10% by biogas. Liquid Fuel is supplied by methanol

FIGURE 3.14

PROJECTED BIOMASS PRODUCTION BY SOURCE

(PETAJOULES)



BU = BUSINESS AS USUAL SCENARIO

CS = CONSUMER SATURATION SCENARIO

and vegetable oil with those sources eventually providing 90 to 95% of the requirements. Any form of biomass can be used as a source of electricity, though the economics are improved when this can be accomplished in a cogenerating situation. However, biomass never accounts for more than a couple of percent of purchased electricity.

Cost estimates were developed for the delivery of biomass energy as specified in Chapter 2. These costs all include allowance for the energy used in biomass production (including harvesting and transportation), and where appropriate also for the purchase of new consumer equipment (as with a wood stove or furnace). Careful attention was paid to the materials balance aspects of the costing and somewhat less to the plant and equipment aspects. Of course, confidence is higher with those systems for which actual experience is available and lower for those systems, notably involving methanol, that do not now exist at full scale. Even in the latter case, uncertainty is generally restricted to only part of the process; for example, it is not the production of methanol that is new but only the use of biomass (instead of, say, natural gas) as the hydrocarbon source.

The resource base from which biomass can be drawn is distinctly limited. In the case of waste products, it is fixed, on the one hand, by the scale of production for the main product or activity and, on the other, by the nature of that product or activity. For example, recycling of paper can reduce the volume of municipal waste available for combustion (though it would simultaneously reduce the energy requirements for the pulp and paper industry), and much straw has to be returned to the soil for agricultural purposes. Also, there are product and activity changes. Many studies have overlooked the fact that the forest industries are trying to use more of their own wastes not as energy but as input (as with the creation of particle board).

In the case of biomass grown for its energy content, availability is limited ultimately by the amount of land of suitable quality but more proximately by the amount of land that is not in demand for other uses. Further, to protect food supplies, no Class 1 land was considered available in the projections to grow biomass energy (except vegetable oil). Thus, the limitations on production of biomass energy are very real. Fortunately, some broad assessments of biomass availability for energy purposes have been made (Love, 1980 and 1981); while tentative, they are more likely to be underestimates than overestimates. In addition, the Canada Land Inventory was used to identify unimproved land considered potentially arable or abandoned farmland that could be used for growing trees for alcohol production (Appendix 2.5). Finally, some additional land can be developed by planting biomass crops in depleted peat bogs.

TABLE 3.13

PRODUCTION AND USE OF BIOMASS FOR ENERGY IN CANADA BY YEAR AND SCENARIO
(Petajoules)

		Primary Sources			Secondary Forms			
Scenario and Year	Source	Production	Availability	Energy Supply Sector	Production	Energy Supply Sector	Use	Form
1978	Forest*	218	215	4	211	-	211	Heat
			4	.	3	-	3	Electricity
BU 2000	Forest (R)	1072	281	3	278	-	278	Heat
			791	295	496	143	354	Methanol
	Forest (H)	689	398	-	398	42	356	Heat
			35	24	11	**	10	Electricity
			256	106	150	36	114	Methanol
	Agriculture (R)	166	83	5	78	-	78	Heat
			83	33	50	10	40	Methanol
	Agriculture (H)	14	14	1	13	-	13	Vegetable Oil
	Manure	103	103	49	54	11	43	Biogas
	MSW	99	99	-	99	-	99	Heat
BU 2025	Forest (R)	1230	213	4	209	-	209	Heat
			1017	285	732	140	592	Methanol
	Forest (H)	2391	507	.	507	46	461	Heat
			104	71	33	**	30	Electricity
			1780	644	1136	240	896	Methanol
	Agriculture (R)	177	96	4	92	-	92	Heat
			81	29	52	11	41	Methanol
	Agriculture (H)	120	27	2	25	-	25	Heat
			93	4	89	-	89	Vegetable Oil
	Manure	237	237	101	136	18	118	Biogas
	MSW	141	141	-	141	-	141	Heat

TABLE 3.13 (Cont'd)

PRODUCTION AND USE OF BIOMASS FOR ENERGY IN CANADA BY YEAR AND SCENARIO
(Petajoules)

		Primary Sources			Secondary Forms			
Scenario and Year	Source	Production	Availability	Energy Supply Sector	Production	Energy Supply Sector	Use	Form
CS 2000	Forest (R)	930	268	3	265	-	265	Heat
			662	250	412	120	292	Methanol
	Forest (H)	622	273	1	272	37	235	Heat
			33	23	10	**	9	Electricity
			316	132	184	44	140	Methanol
	Agriculture (R)	167	84	3	81	-	81	Heat
			83	33	50	10	40	Methanol
	Agriculture (H)	14	14	1	13	-	13	Vegetable Oil
	Manure	103	103	49	54	11	43	Biogas
	MSW	127	127	-	127	-	127	Heat
CS 2025	Forest (R)	981	144	3	141	-	141	Heat
			837	251	586	122	464	Methanol
	Forest (H)	1738	438	1	437	44	393	Heat
			97	68	29	**	26	Electricity
			1203	434	769	174	595	Methanol
	Agriculture (R)	176	86	3	83	-	83	Heat
			90	32	58	13	45	Methanol
	Agriculture (H)	94	16	1	15	-	15	Heat
			78	4	74	-	74	Vegetable Oil
	Manure	243	243	103	140	18	122	Biogas
	MSW	114	114	-	114	-	114	Heat

GENERAL NOTES FOR TABLE 3.13

1. This table is identical in concept and format to Tables CA-2 and CA-12 through 15 except that three columns have been eliminated. There is no international trade in biomass products so that the two net inflow columns can be eliminated. Also, the column for non-energy use can be eliminated, as this column would represent, say, wood used as a construction material (which cannot be included as a secondary form on the right because only wood used for energy purposes is included as a primary source on the left).

2. This table has been built up from provincial information on the production and use of biomass. However, some provincial analysts only demonstrated that there was sufficient biomass of appropriate types to satisfy the required demands without specifying the particular mix that would be used. In such cases, it was necessary to project a mix for the purposes of this table using general guidelines, such as to favour the use of residues over harvested biomass (subject to a qualifying economic judgement not to take more than about half of residues potentially available). In general, crop residues were used primarily for heating and wood residues primarily for liquid fuel.

3. Excluded from this table are those logging, mill and farm residues that are used within an establishment or sold locally without passing through a conventional market.

4. The distinction between forest and agricultural residues ("R") and forest and agricultural harvesting ("H") is that the former requires no additional land use beyond what would be taken for the main product, whereas the latter involves some form of dedicated land use ranging from woodlots and surplus forage to energy crops and plantations. The distinction thus hinges on land use, not on the nature of the source. Harvesting of trees damaged by spruce budworn or of unwanted species on second-growth forest is therefore tabulated as H, not R.

SYMBOLS

R	-residues
H	-harvested
MSW	-Municipal Solid Waste
.	-less than 0.5 PJ

OTHER NOTES

*	No distinction could be made between Forest (R) and Forest (H) in 1978.
**	A 10% allowance for line loss was deducted prior to determining secondary electricity production

Of course, what is more important than national comparisons of biomass supply and demand are provincial and regional ones. The analyses indicate that the additional demands for land identified in this report can be accommodated on a national basis, but that deficits exist in some provinces, largely because of wide variations in provincial resource availability. Figures 3.7 and 3.8 show that provinces rely to quite different degrees on biomass in secondary use by 2025, and Figures 3.11 and 3.12 show that primary production of biomass is even more disparate. Excluding the territories, the range for the share of biomass in secondary energy use in 2025 is from 25% in Newfoundland and Nova Scotia to more than 60% in the western provinces. The range for the shares of production is even wider. In absolute terms, biomass use goes from 5 PJ per year in Prince Edward Island to nearly 900 PJ per year in Ontario.

The sources and uses of biomass energy by province are shown in Table 3.14. It is apparent that some biomass sources are much more important than others and that some uses are much more common than others. It is convenient to divide the sources into municipal, agricultural and forest origins, as in Table 3.14.

Municipal solid wastes contain about 11 GJ per tonne but are a feasible energy source only in urban areas as substantial volumes are required to justify construction of a district heating or cogenerating facility with the special equipment (and pollution control devices) necessary to handle a wet, highly variable mix of materials. Experience with such plants has been mixed, and only a few provinces considered municipal wastes worthwhile as an energy source. Such plants generate a few to a few tens of petajoules per year. Annual production of secondary

TABLE 3.14

SOURCES AND USES OF BIOMASS BY PROVINCE, BUSINESS AS USUAL SCENARIO IN 2025

	NF	NS	PE	NB	QU	ON	MN	SK	AB	BC	YT	NT
SOURCES												
Forest Industries												
Forest Residues			O	X	X	O	O	O	X	X	X	O
Mill Residues (Forest)	X	X	X	X	X	O	X	O	O	X		
Managed Forest Growth	X	X*	X*	X*	X	X		X	X			
Fast Growing Plantations			X	X	X	X		X	X			
Agriculture												
Oil Seeds								X	X			
Other Crops								X				
Crop Residues						O	O	X				
Straw						O	X		O			
Animal Wastes					O	O	O	O	O			
Other												
Municipal Waste			O		O	O		O	O			
USES												
Process Heat												
Heating & Cooling	X	X	X	X	X#	O#	X#	X#	X#	X#	X	O
In Plant Use at Source**	X	X	O	X	X	O	O	O	O	X	O	O
Other					O	X	O	X	X			
Electricity Generation (except cogeneration)			O	O					O			
Liquid Fuel	X		O	O	X	X	X	X	X	X		

Key : O - Indicates some source or use.
X - Indicates major source or use relative to that province's total.

Notes: * - Includes large areas of privately owned woodlots.
** - Includes cogeneration.
# - Includes locally distributed biogas.

energy in petajoules from municipal solid waste in 2025 is shown in Table 3.15.

TABLE 3.15

SECONDARY ENERGY PRODUCTION FROM MUNICIPAL SOLID WASTE IN 2025

Prince Edward Island	<1	(Charlottetown)
Quebec	28	(Montreal and Quebec)
Ontario	102	(Several)
Saskatchewan	2	(Regina and Saskatoon)
Alberta	9	(Edmonton and Calgary)
Canada	142	

Agriculture offers a somewhat greater potential as an energy source. As stated in a recent review article:

> "The technical constraints on agricultural biomass energy appear to be few and minor. The economic impacts are less well understood, but do not appear to limit biomass production in the near term" (Flaim and Hertzmark, 1981).

Where animals are confined within feedlots, manure (22 GJ per oven dried tonne - ODt) becomes a disposal problem and, even allowing for a considerable volume returned to the soil, some can be used as an energy source. Much the same is true of straw (15 GJ/ODt), though some provinces felt that eventually all straw would be needed as a soil conditioner and hence identified no surplus for energy use. In either case, waste materials can be dried and burned for heat or, as is more common with manure, used as input to a digester which produces impure methane. (Such digesters are the source of all the biogas that appears in this study.) In all cases, the energy must be collected and used within a relatively small area as neither the original sources nor the secondary forms are particularly dense in energy content. In most cases, only local collection and use is anticipated, but in Alberta straw is transported up to 100 km at $25 to $30 per tonne. As elsewhere in this report, those quantities of agricultural residues that go to provide energy within an establishment (that is, on the same farm where they are produced -- or possibly on a neighboring farm or processing palnt) do not appear as increases of renewable supply but rather as decreases of demand. For this reason, and because of the environmental uncertainties involved, the quantities of energy obtained from agricultural residues and manure in this study are relatively modest, as shown in Table 3.13 and in Table 3.16. It is likely that with greater attention to this source two to four times as much energy is safely obtainable from these sources.

TABLE 3.16

SECONDARY ENERGY PRODUCTION FROM MANURE, STRAW AND OTHER AGRICULTURAL RESIDUES, BUSINESS AS USUAL SCENARIO

(Petajoules)

	Manure		Straw		Other	
	2000	2025	2000	2025	2000	2025
Quebec	*	*	--	--	--	--
Ontario	26	43	36	42	--	--
Manitoba	*	*	5	4	*	*
Saskatchewan	<1	1	--	--	31	37
Alberta	16	75	47	51	*	*
Canada Total	43	118	88	97	31	37

* Large quantities used locally.

In most provinces the quantities recovered were held constant with time, but in a few they were escalated at rates of growth below that of the agricultural industry.

Crops and crop wastes are a potentially large source of energy though ones that can conflict with food production. This study took as a principle that any direct conflict between energy crops and food crops would be resolved in favour of the latter. In part for this reason, only in Saskatchewan was a great potential recognized for use of crop wastes (other than straw) beyond what could be used on the farm itself or returned to the soil. The volume of energy was 31 and 37 petajoules in 2000 and 2025, respectively, derived from crop residues and another 37 petajoules (2025 only) derived from additional cropping and forage from native pastures that is surplus to the needs of livestock. (In contrast, a recent study in the United States, a country that of course has a much greater area planted to crops than does Canada, found an enormous energy potential in crop wastes (Ross and Williams, 1981.) However, Alberta and Saskatchewan did identify a major potential for growing oil seeds as a replacement for diesel oil, mainly after 2000.[5] Saskatchewan projected production of 32 petajoules of energy as vegetable oil by 2025, and Alberta projected 46 petajoules using only land that is currently left in summerfallow. (Summerfallowing is now considered to be an unwise practice for the soil of western Canada (Jensen Engineering, 1981, p. 57).) It is likely that the potential for expanding the production of vegetable oils (or of other vegetable sources of hydrocarbons) has been underestimated in this study. For example, Saskatchewan could provide its vegetable oil needs (which replace all other Liquid Fuel in agriculture, including the transportation requirements, by 2025) using only 28% of land currently in summerfallow (assuming yields of 1000 Kg per hectare). However, there are too many unknowns at this time to project production beyond the levels identified in this study. Moreover, while there is no direct conflict with food production at the projected levels of production, an indirect conflict could arise if vegetable oils became valuable enough to induce farmers to sell canola (for example) as fuel instead of as food or to shift land that would otherwise be growing food into energy crops.

Despite the variety of opportunities for biomass energy identified in urban areas and in agriculture, the great opportunity for establishing a sustainable energy supply for Canada lies with her forests. Canada has long been a major world producer and exporter of wood and wood products. That same resource base now offers a permanent resolution for part of the energy problem and one that, if properly managed, would complement rather than conflict with existing forest industries.

Apart from passive solar and hydropower, wood is the only renewable energy source in wide usage today. In 1978 fuel wood and wood wastes together contributed more than 4% of our energy secondary energy use (Rubin, 1980). The opportunities for expanding the supply of forest-based energy are varied in detail, but for purposes of generalization they can be divided into four categories, two involving waste products and two involving new growth. The first of the wastes involves logging residues, which are the materials left behind in the forest at the time currently marketable wood is harvested. Logging residues include the limbs, foliage and upper trunk lopped off wood before hauling to mills plus diseased and decayed trees. The second of the wastes are mill residues found at saw mills, pulp mills and other forest industries. They include combustible or digestible wastes in the form of saw dust, bark, black liquor and so on. Mill residues have an immediate value as they have already been collected whereas logging residues have not; moreover, use of mill residues relieves a pollution problem whereas collection of at least some of the logging residues (e.g. roots and foliage) may create one.

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[5] Calculations for the purpose of this study assumed that the crop was rapeseed.

New growth from forests can be obtained either from improved management within existing land-use patterns or from plantations with fast growing species. (Some additional wood could be harvested from private woodlots without more management, but the quantities available would not come close to the demands identified in this report.) It is widely recognized that forest management in Canada offers a substantial potential for increasing the total yield of forest land. It could also aim at multiple use so that the forests simultaneously produce wood for energy and for non-energy products. Energy crops could, for example, result from progressive thinning in timber plots or from mixed cropping with non-pulp species (e.g., aspen, willow, alder) being used for fuel wood or as a source for methanol (Hewitt et al , 1981). In contrast, growing of trees as energy crops on plantations is a single-purpose use of land, and generally involves the planting of fast-growing species such as hybrid poplar with harvests every five to ten years. Yields of 18 to 54 ODt per hectare-year have been reported (see Appendix 2.5), but the higher levels also incur the highest dollar costs and the highest environmental risks.

The statistical problems that dog any energy study arise to an even greater degree with biomass. Despite the evident opportunities, and the fact that biomass is already a highly competitive source of heating in Canada, good information on either the existing supply or the sustainable harvest is very difficult to obtain. For example, a review of energy opportunities in Nova Scotia found that provincial data and federal data on just the use (not the total supply) of mill residues alone differed by a factor of four (Brooks and Perras, 1981, p. 70). Estimates of the volume of logging residues commonly vary by an even greater factor, and of the volume that can be safely removed (for environmental reasons) by even more. With such variability in the estimates for existing waste, it is easy to imagine the range in estimates of potential for new growth in managed forests or plantations. Further complicating the resource estimates are concerns as to whether, at today's rates of replanting, the existing level of production in the forest industry is sustainable, much less the levels of production projected by the LTSM. Sadly, the record of land use in Canadian forests has been one of mining rather than sustainable yield, and this would have to change in order for biomass to play the major role in Canada's energy future that is projected here.

Before undertaking a province-by-province review of the role of wood biomass in this study, it is useful to summarize the national results very briefly:

(1) Mill residues will be used largely to make the forestry and pulp and paper industries essentially self-sufficient in energy supply (no small matter given that they accounted for almost 10% of total secondary energy use in Canada in 1978);

(2) all provinces can find adequate biomass resources within their borders to satisfy fuel wood requirements for Heating and Cooling energy and even for Medium-Temperature Process Heat; but

(3) about half the provinces find that, even with plantation crops on the one hand and a shift to electric vehicles or CNG in cities on the other, deficits arise in the supply of biomass from within the province that can be used as a source for Liquid Fuel.

As will be seen below, one result of these conclusions is that today's interprovincial trade in crude oil and refined petroleum products is replaced in the projections by interprovincial trade in biomass fluids, albeit at much lower volumes.

The Newfoundland report describes wood as the "most problematic" of the renewable sources because of growing demands for forest land from pulp and paper mills.[6] However, non-pulp species are available in sufficient quantities to provide all fuelwood needs at well below sustainable yields throughout the projection period at $1 to $2/GJ. Ironically, spruce budworm damage will increase the supply, particularly for processed or particalized fuels. Within the industry, whole tree chipping of hardwoods as a substitute for heavy oil is already underway. However, methanol is a problem. To supply Liquid Fuel needs in 2000, beyond those available from the province's assumed level of oil production, only a single methanol from wood plant would be necessary. Although the required input would be ten times what is now recognized as surplus, this is "probably not unreasonable if 'waste species' such as aspen and poplar are utilized and if the harvesting is coordinated with pulp or lumber cutting".[7] However, no great expansion of this harvest is considered feasible (nor is any production of vegetable oils seen as likely in Newfoundland's climate). Hence as conventional petroleum supply falls off in 2025, the additional biomass fluids must be imported from other provinces.

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[6] To avoid complicating the province-by-province review, no explicit citations are given. Any material within quotation marks can be found in the appropriate provincial chapter of Volume II. Also, unless otherwise stated, all discussion refers to the Business as Usual scenario, as this scenario highlights any problems. In most cases biomass requirements are lower in the Consumer Saturation scenario because total energy requirements are lower and because conventional energy supplies extend further into the future.

[7] The use of "waste species" as input for a methanol plant explains the discrepancy between the provincial report and Appendix 2.5 which finds no potential for methanol in Newfoundland. The latter depends entirely on unimproved and abandoned farmland for input, and such land is negligible in Newfoundland.

Forest biomass plays a smaller role in Nova Scotia than in other provinces. Biomass solids produced within the province and used within the forest industries and as woodfuel in the Residential and Commercial sectors grow from 2% of secondary use in 1978 to about 10% in 2000 and 11% in 2025. It is expected that this level of production could be maintained, largely through better management of private woodlots. However, the province's extensive softwood forests are already being harvested beyond sustainable limits, and the industry is planning to harvest hardwood, so there is no surplus of forest biomass that is clearly available to produce methanol. Hence, all of the projected requirements for biomass fluids in Nova Scotia are imported from other provinces.[8]

Wood will be relied upon heavily in Prince Edward Island, with production from intra-provincial sources growing from 11% of secondary use in 1978 to 34% in 2025 in the Business as Usual scenario, and to 87% in the Consumer Saturation Scenario. The wood will be supplied as a mix of roundwood, chips and pellets for space and water heating in the Residential, Commercial and Industrial sectors and for process heat in the Industrial. The existing harvest of fuelwood, plus that cut for timber and pulp, could be doubled by use of waste products, most of which can be converted to wood chips economically. Enough wood for both projection years could be provided from improved management on less than half the currently forested area of Prince Edward Island. Only in the Consumer Saturation scenario in 2025 is methanol production foreseen and then only one plant. However, to produce enough wood to supply that plant, as well as other demands, 70 thousand hectares (29% of the province's forestland) would have to be devoted to plantations (including allowances for roads, streams and other unproductive areas and for the energy requirements of harvesting and methanol production), and another 40% would have to be intensively managed; only about 30% would be left "wild". If this option is not followed, requirements for biomass fluids will have to be imported from other provinces.

Forests cover 88% of New Brunswick's land mass and are projected to play a major role in the province's energy future. As a proportion of secondary use, biomass grows from 13% in 1978 to 37% in 2025 (both scenarios) and, together with hydropower, is largely responsible for increasing the use of intraprovincial sources from 19% to over 60%. "However, central to the question of the use of wood as an energy source is the larger question of the availability of wood generally within the province." The province is probably already exceeding its sustainable cut of softwood, at least with current levels of forest management. The forest industries are moving to use more of their own waste products; in 1978 an estimated 36% of the energy requirements of pulp and paper mills were produced from hog fuel and pulping liquor, and this share (including allowance for cogenerated electricity) is expected to grow to 75% in 2025. In contrast, the use of fuelwood (already supplying 8% of urban and 23% of rural residential requirements) is expected to face resource limits in the near future, so its absolute contribution was held constant. (The relative role of fuelwood does increase as conservation measures reduce fuelwood use per household.) Turning to methanol, a special analysis (see Appendix 2.3) indicated that, once the forest industries' own requirements for waste products and anticipated requirements for hardwood were subtracted, little surplus was left that could be devoted to a methanol industry. Based mainly on logging residues and keeping to a collection radius of 160 km., New Brunswick could support only three 200 tonnes-per-day plants (one each in the Northeast, the Miramichi area and in the southern part of the province). In addition, plantations on class 2 to 4 farmland or on depleted peat bogs could support one 1,000 tonnes-per-day plant in 2000 and a second one in 2025. In total, these plants would produce only 17% of the province's projected liquid fuel needs (26% in Consumer Saturation). The remainder would have to be obtained from other provinces.

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[8] For a contrasting view, see Appendix 2.5, which indicates that more than enough methanol could be produced from unimproved but potentially arable land and abandoned farmland in Nova Scotia. However, the land survey on which the appendix is based did not take account of the redevelopment of farms and of the land requirements to grow wood as a heating fuel.

Along with hydropower, forests play the dominant role in Quebec's energy future, and offer the potential for a fully renewable source of supply. Their use grows to 18% of total secondary use in 2000 and 48% in 2025, and in addition by the latter part of the study period a potential for export of biomass fluids on the order of several hundred petajoules per year (more than the total deficit of all the Atlantic provinces) has been identified.[9] The major sources are the forest industries themselves, with about 100 petajoules per year, enough to make them largely self-sufficient; logging residues of some 200 petajoules per year (excluding roots and stumps, which are left for environmental reasons); and recuperation and management of currently degraded or non-productive forests, which are estimated to have a potential of 240 petajoules per year. In addition, some 5 million hectares of potentially arable or abandoned farmland have been identified as sites for energy plantations. In the year 2000, 20% of this land was assumed to be planted to fast-growing species. How much of this land would in fact be needed depends not so much on Quebec's own requirements for Liquid Fuel, which can mostly be met from non-plantation sources, as from the potential for creating a new energy-export industry within the province.

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[9] The indicated export of 300 to 400 PJ/a includes 15 to 20 PJ/a from peat as a source.

The combined demands for both biomass energy and traditional forest products in the pulp and paper industry present a very tall order for Ontario forestry. However, the concentration of the market in Ontario presents greater opportunities than in most provinces for the early development of energy forests. Irrespective of the development of the biomass market, the future of forestry in Ontario depends on the marshalling of sufficient resources to increase the regeneration of cut-over areas. The energy value of the biomass stock on millions of hectares of second growth Great Lakes and Boreal forests in Ontario could aid in this expensive but inevitable task, and the supply of biomass from this "clean-up" operation provides the major component of the forestry based biomass production in the first part of the study period. In the longer term, a number of production modes are envisaged, ranging from conventional forestry (where the biomass market claims the culls and logging wastes) to coproduct forests (where a variety of species are grown for lumber, fibre and energy) to dedicated energy forests (where species are selected for their rates of biomass growth) to intensively managed short rotation energy plantations. The densified wood pellet becomes the basic commodity from all these sources, feeding both the direct fuel and the methanol feedstock markets. It should be noted that, in an effort to achieve a high degree of biomass self-reliance, the pressure on the land base would be much greater in Ontario than in either of her neighboring provinces. This could result in biomass and/or methanol flows into Ontario from Quebec and Manitoba at much higher levels than have been assumed in our projections, with a corresponding shift in the demands on the land base of each of the three provinces.

Manitoba's forests do not make a major contribution to that province's energy requirements until after 2000. In the first part of the study period, wood provides less than 10% of secondary energy use, mainly for heating residences (plus industrial process heat in the Consumer Saturation scenario in which natural gas is backed out more rapidly). The main limitation on the use of wood is the speed at which a transition can be effected. By 2000, pellets are the cheapest form of energy available in the province, and the potential surplus of mill residues alone is more than enough to fill heating requirements. By 2025 half of Manitoba's energy use could come from wood. The main use of wood shifts from heating to methanol production, and with this shift wood wastes are no longer sufficient for requirements. However, a choice remains inasmuch as the province could depend either on the development of plantations to provide the necessary input or on non-forest sources of biomass, including straw and crop wastes. Manitoba would neither import nor export wood as energy.

The potential for deriving energy from forests in Saskatchewan is fully as large as that from agriculture. More complete harvesting of the allowable cut of hardwood (mainly aspen) could yield over 50 petajoules per year, with the potential more than doubling if intensive silviculture is practiced or high-yield varieties planted. (Some 40% of the productive forestland in the province is not now being harvested at all.) Another 100 petajoules or so could come from mill and logging residues plus trees surplus to or not acceptable in the province's forest industries. Based on these sources, the potential contribution of wood is expected to grow to about 200 petajoules in 2000 and 250 petajoules in 2025, though by no means all of this energy is needed, given Saskatchewan's choice not to export biomass-derived energy so as to reduce pressure on the environment. The wood is used mainly for process heating at first (including that used in the forest industries), but after 2000 wood plays its major role as a source for methanol, which eventually replaces all refined petroleum products in transportation except for mainline railroads, which are electrified. (The vegetable oil replacing diesel oil is used exclusively in agriculture and so appears in the Industrial sector.) In total by 2025, 132 to 165 PJ of biomass are used for heat and for methanol (besides the 32 PJ of vegetable oil).

Alberta is similar to Saskatchewan in that its potential production of forest biomass is as big as or possibly bigger than that from agriculture. Currently surplus mill residues amount to nearly 30 petajoules per year. Together with logging residues and trees not taken by the forest industries, about 375 petajoules per year could be available after 2000 at prices of $44/ODt or just over $2/GJ. An equal or even greater potential exists by developing plantations on some of the 8 million hectares deemed suitable. Because much of this land is located in the northern part of the province, yields would be low: 2 to 4 tonnes per hectare-year on a sustainable basis, without much management. However, production could reach 90 petajoules per year in 2000 and 400 petajoules per year in 2025. Based on this abundance of relatively low-cost energy, wood provides about 5% of Heating and Cooling energy in 2000 and about 15% in 2025, mainly as a substitute for natural gas in buildings where both space and water heating are required. Wood also takes over a large share of industrial process heat. Including usage within the forest industries, it accounts for 25% of the requirements in both 2000 and 2025. A small amount of electricity is provided by wood-fired generators. And of course wood provides the major input to make methanol, which provides 40% of the Liquid Fuel requirements in 2000 and over 75% in 2025. Over 200 petajoules per year are produced, enough to provide a substantial surplus for export to other provinces. Vegetable oil is also produced in quantities large enough for interprovincial shipments. However, land requirements are high. In the highest biomass case (year 2025 in the Business as Usual scenario), almost one-fifth of the provincial land area (and twice as much land as is currently devoted to agriculture) would have to be used for energy production, though this figure includes the low-yield land managed very extensively in the northern part of the province.

The forest situation in British Columbia is different from that in any other province because of the enormous biomass surplus from mill and logging residues alone, even if no other biomass sources are considered. At costs per gigajoule of around $2.50 for waste wood in 2000 (growing to $9 by 2025 as all of the wastes come to be used), and $9.50 for methanol in 2000 (growing to $12 by 2025), wood is highly competitive both on the coast and in the interior of British Columbia. Maximum biomass use occurs in 2025 in the Business as Usual scenario. Some 165 petajoules is used as heat (including one-fifth to one-fourth of the Heating and Cooling and almost all of the Medium-Temperature Process Heating, which is dominated by the pulp and paper industry) and almost 450 petajoules as methanol. In the same year, the available supply of biomass in wastes would be almost 800 petajoules, which is clearly adequate. If the pulp and paper industry does not expand by a factor of three, as projected by LTSM ("with the best forestry and utilization techniques, biomass production is unlikely to increase more than 50%"), both demand for and supply of biomass energy would decline in parallel without seriously changing the balance between them. Unused in the scenarios but potentially usable are large volumes of forest biomass in the form of red alder which is the main succession tree when conifer forests are clear cut. It is capable of producing 18 ODt per hectare-year with rotation times of ten years or less, and could be seen as a coproduct of softwood harvesting in a managed forest industry.

Finally, wood use in the two Territories is severely restricted because of limited forests and slow growth rates. As a result no Biomass Fluids at all are produced in the Territories and only modest increases are projected in the production of Biomass Solids. All of this increased production occurs by the year 2000 and amounts, in the Business as Usual scenario, to an increase of 25% in the Northwest Territories and 100% in the Yukon. This energy is used mainly for heating in the Residential and Commercial sector but it includes some small-scale electrical generation.

3.5 ENERGY BALANCES IN 2000 AND 2025

Section 3.3 focussed on demand and Section 3.4 on supply in a soft energy future for Canada. In this section the two will be brought together. Because thermodynamic quality categories are the organizing principle for soft energy analyses, they will be used to organize this chapter. The objective is to increase system efficiency by matching sources of energy to uses of energy in ways that, so far as possible, minimize conversion losses and transportation and transmission losses (with "losses" being interpreted in both its thermodynamic and its economic senses).[10]. In addition, two categories of energy use about which little has been said to now must be described: non-energy products and the Energy Supply sector. Both appear statistically as a part of primary production but not of secondary use, as indicated on Tables CA-2 and CA-12 to CA-15. In Section 3.6 below, the remaining columns of Tables CA-12 to CA-15, those dealing with imports and exports, will be covered.

The energy balances discussed in this section are summarized in Figures CA-1, CA-4, CA-5, CA-7, and CA-8 at the end of the chapter (as usual, one for 1978 and one for each of the two scenarios in 2000 and in 2025). These five pie diagrams show how energy of different qualities is distributed in Canada. Comparable pie diagrams in each provincial volume of the report show the same for each province. As explained in Appendix 3.1, the wedges of the pie charts expand consistently outward to show how energy of each quality category is both used (the outer circle) and supplied (the bars). Thus, each pie diagram summarizes the energy balance for one region in that scenario and year.

Before proceeding into a review of energy use and supply by quality categories, it is useful to summarize the overall changes that take place across Canada in the two scenarios. Table 3.17 illustrates the changes in the provincial and territorial shares of total Canadian energy use and primary production in each scenario and year. This table summarizes the information contained in Figures 3.7, 3.8, 3.11 and 3.12, which were discussed in previous sections. The relatively constant provincial and territorial shares of total energy use are clearly evident there, as are the major changes in the provincial and territorial shares of total energy production. In general, while each province or territory accounted for a similar proportion of national energy use in 2025 as in 1978, all provinces except Alberta and Saskatchewan increased their share of national energy production over the projection period. In the case of Quebec and Ontario especially the increases were

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[10] This approach, generally described as matching by quality and by scale, is fundamental to soft path analysis. It is described in any review of soft paths (e.g., Lovins, 1977; Brooks and Casey, 1979). See also the discussion in Chapter 1, above.

TABLE 3.17
DISTRIBUTION OF TOTAL SECONDARY ENERGY USE AND TOTAL PRIMARY PRODUCTION BY PROVINCE, 1978 AND 2025
(vertical percentages)

Province	Secondary Energy Use			Primary Energy Production*		
		2025			2025	
	1978	Business As Usual	Consumer Saturation	1978	Business As Usual	Consumer Saturation
Newfoundland	1.9	1.9	1.7	0.7	2.5	2.2
Nova Scotia	3.1	3.1	3.4	1.4	2.3	2.5
Prince Edward Island	0.3	0.3	0.3	< 0.1	0.1	0.2
New Brunswick	2.8	3.6	3.5	0.5	1.9	1.9
Quebec	24.9	20.7	21.4	4.5	20.4	21.7
Ontario	34.8	36.3	35.9	7.1	17.4	18.6
Manitoba	3.7	2.7	2.8	1.2	1.7	1.8
Saskatchewan	4.3	3.7	3.9	7.9	3.6	3.4
Alberta	11.2	13.7	14.2	64.2	34.4	32.7
British Columbia	12.6	13.2	12.4	12.3	15.5	14.9
Yukon Territory	0.2	0.2	0.2	<0.1	<0.1	<0.1
Northwest Territories	0.3	0.4	0.4	0.2	0.2	0.1

Note: For the purposes of this table, total primary production is defined to exclude international exports in order that the focus can be on that volume of production needed for Canadian use.

significant.

It should be remembered that, because the figures shown in this and succeeding tables are in percentages, in most cases they occur within decreasing overall energy use. Hence, any decline in the share of use represents a proportionately greater decline in the absolute level of use; any increase in share represents a proportionately smaller increase in absolute use. However, between 1978 and 2000 in the Business as Usual scenario, energy use increases slightly, so these relationships are reversed; declines in share are smaller and increases in share are greater in absolute terms.

Changes in the Distribution of Energy Use by Quality

Figures 3.15 and 3.16 show changes in total secondary energy use and its distribution by quality categories. Much of the change in the quality distribution occurs between 1978 and 2000. As with the sectoral distribution, almost the same patterns are exhibited by the two the two scenarios, as indicated in Table 3.18.

The three biggest changes are the reduction in the share of energy used for Heating and Cooling, which including Low-Temperature Process Heat in industry, the increase in the share used for High-Temperature Process Heat and the increase in the Electricity Specific share. Heating and Cooling energy declines steadily over the projection period with the gradual introduction of construction techniques that practically eliminate the need for space heating in the Residential and Commercial sectors. High-temperature energy increases partly because of the growing share of energy used by the Industrial sector and partly because relatively smaller economies are available for subsectors that need high-temperature heat. The increase in the Electricity Specific share reflects the use of motors and equipment as well as use of electricity in the Commercial sector and as motive power for transportation.

A few other changes in the shares for energy quality categories are worth noting. The share of energy used as Mid-Temperature Process Heat grows at first but declines during the second half of the projection period as a result of growing investment in cascading techniques. Finally, Liquid Fuel use declines at first and then partially recovers, which not surprisingly parallels the pattern of change for the Transportation sector.

FIGURE 3.15

SECONDARY ENERGY USE IN CANADA BY QUALITY, BUSINESS AS USUAL SCENARIO

(PETAJOULES)

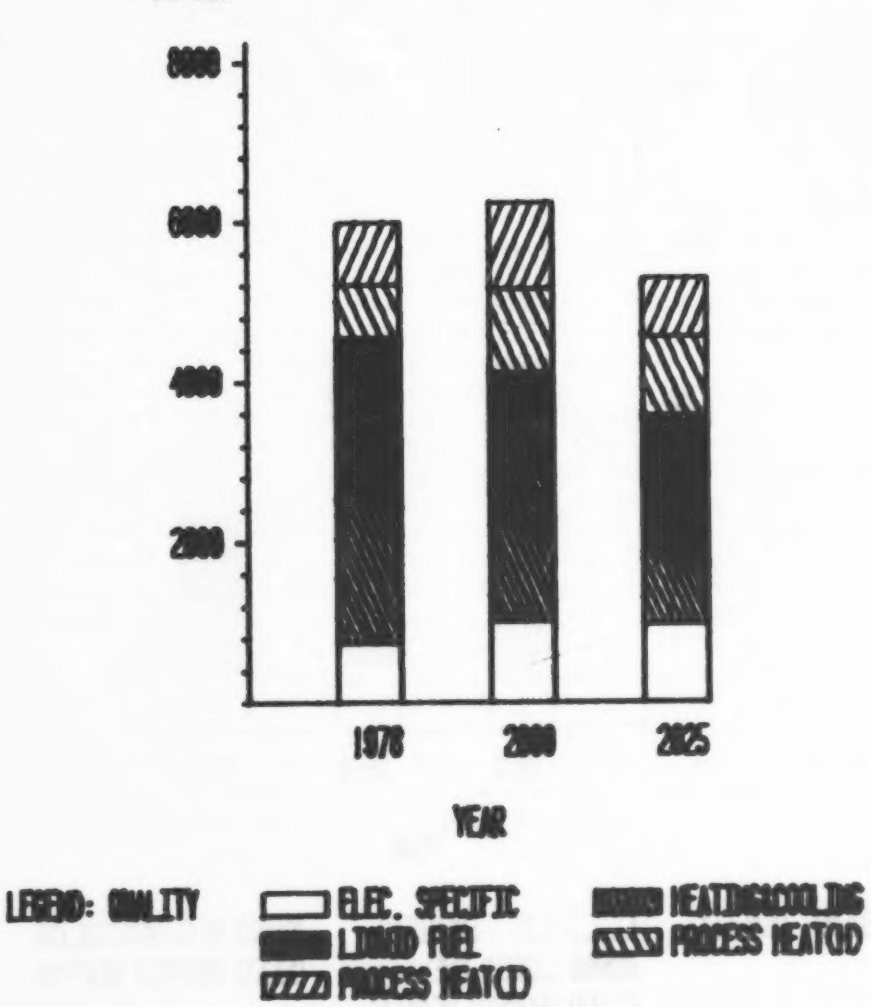

FIGURE 3.16

SECONDARY ENERGY USE IN CANADA BY QUALITY, CONSUMER SATURATION SCENARIO (PETAJOULES)

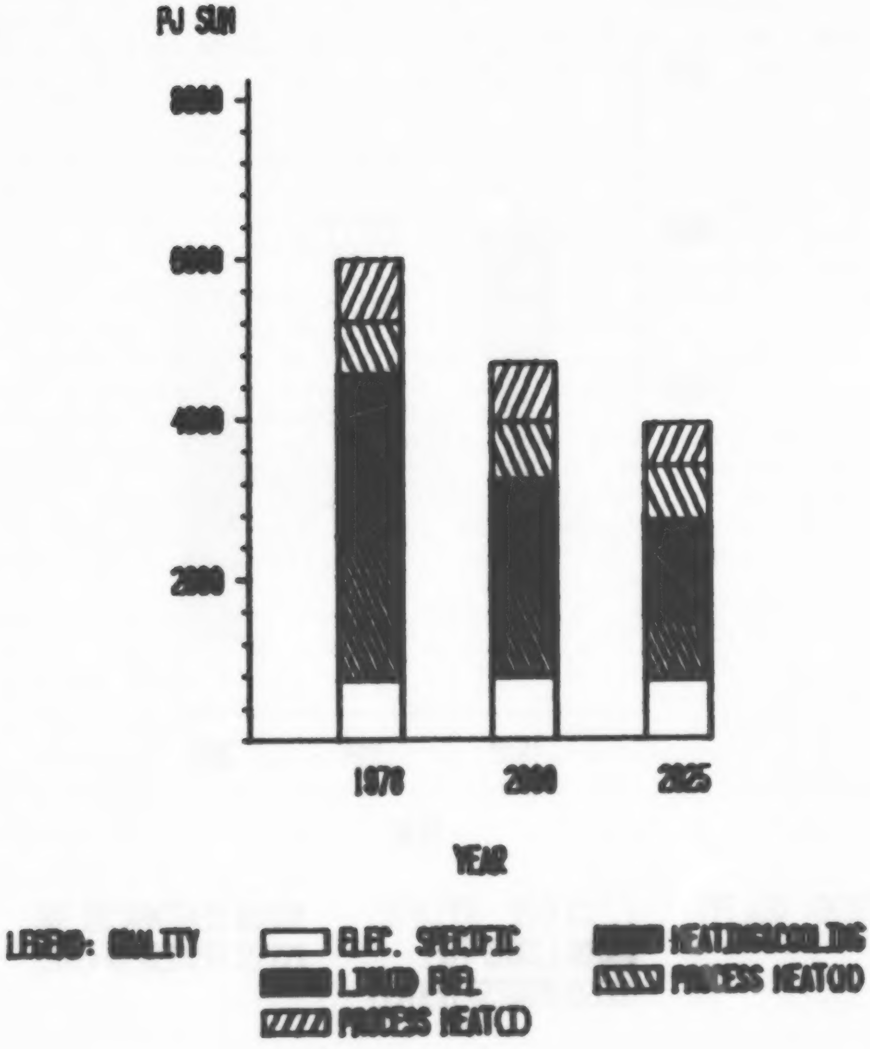

TABLE 3.18

PERCENTAGE SHARES OF SECONDARY ENERGY USE BY QUALITY

		Business as Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Heat and Cooling[11]	30	19	17	23	20
Process Heat (100-260°C)	13	17	14	16	13
Process Heat (above 260°C)	11	17	19	16	18
Electricity Specific	12	16	19	17	19
Liquid Fuel	33	30	32	29	30

Heating and Cooling

As indicated above and as shown on Figures CA-4, CA-5, CA-7, and CA-8, Heating and Cooling takes less and less energy over time. Moreover, long-distance transportation of energy for this purpose also declines. What has happened is that the requirements have been cut back sharply by conservation measures that are already cost-effective, and most of the remaining requirements can be met by low-quality, generally locally produced, sources of energy. Where transportation is still involved, it represents a transition that is still incomplete in 2025. Thus, natural gas continues to supply energy for Heating and Cooling in 2025, but mainly in older buildings. The use of biomass solids and biomass fluids (mainly biogas) has grown over the same period, and electricity provides most of the remainder. This last result arises because, ultimately in decision making, thermodynamics gives way to economics, and in most provinces electricity is the cheapest way to provide the small amount of back-up heating required in super-energy-efficient buildings. Finally, in remote areas there will always be a need for some dense, packagable form of fuel, and this is likely to be a petroleum or natural gas derivative or biomass fluid. Table 3.19 in the next section shows the changes in the forms of energy that provide Heating and Cooling.

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[11] Includes industrial process heat at less than 100 degrees C.

Process Heat

In the higher temperature ranges, the sources of process heat change rather less in the scenarios here than do those of other energy qualities. This lack of change stems from a principle developed in one of the supplementary studies (see Appendix 2.3) to the effect that "hard" industries should run on "hard" energy sources because of the intensities involved. For example, smelting is likely to continue to depend upon coal as a heat source and electricity will continue to be used for melting where point-of-use cleanliness is essential. While some switch away from oil as a source was incorporated except in the provinces where it is produced, coal remains a major source of High-Temperature Process Heat, as does natural gas to lesser extent. However in both scenarios, Biomass Solids become the largest single source by the year 2025.

As shown in Figures CA-4, CA-5, CA-7, and CA-8, with Medium-Temperature Process Heat there is more opportunity for new and renewable sources to come into use. For one thing, industries which produce combustible wastes, such as wood products and food and beverage, will begin to use them, and those that can accept dirty heat, as with cement, will use urban wastes. For another, biomass and peat can provide medium-temperature heat economically and so, by the end of the study period, can active solar systems.

The same results are shown in Table 3.19 below which shows the percentage distribution of energy forms used at various temperatures ranges (less than 100^0C, 100 to 260^0C and above 260^0C). The two scenarios do not differ substantially except that the transition is carried further in Consumer Saturation; that is, conventional nonrenewable energy forms drop to a lower share and new renewable ones come to provide a greater share of heating energy than in Business as Usual. The small but growing role for active solar systems is evident, particularly at the lower temperature ranges, as is the larger and almost dominant role played by biomass at all temperature ranges. (Biomass finds its greatest relative role in providing Medium-Temperature Process Heat.) As indicated elsewhere, the role for electricity changes very little in absolute terms over the full 47-year period, though somewhat more is required in the Business as Usual scenario in the year 2000.

In brief, higher quality energy sources can, in a soft future, be devoted to producing the higher temperatures required by industry, whereas lower quality sources can be devoted to lower temperature process heat and space and water heating. This shift is brought out by figures showing the distribution of energy forms used to produce heat at each of the three temperature ranges.

TABLE 3.19

DISTRIBUTION OF SECONDARY ENERGY USED AT VARIOUS TEMPERATURE RANGES BY FORM
(percentages)

		Business as Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
A. Heating and Cooling (less than 100°C)					
Coal	<1	<1	1	<1	1
Natural Gas	44	47	27	50	21
RPPs	45	11	2	5	1
Electricity	10	19	20	19	19
Biomass	1	14	28	16	34
Active Solar	--	8	22	9	24
B. Medium-Temperature Process Heating (100 to 260°C)					
Coal	3	5	4	4	5
Natural Gas	42	32	16	33	8
RPPs	29	6	1	4	1
Electricity	1	2	3	2	2
Biomass	25	53	62	53	68
Active Solar	--	3	14	3	15
C. High-Temperature Process Heating (260°C)					
Coal	22	28	35	28	36
Natural Gas	39	42	16	34	5
RPPs	29	7	3	6	2
Electricity	10	6	4	5	7
Biomass	<1	16	41	27	49
Active Solar	--	<1	1	<1	1

**SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983**

Heat requirements represent the largest share of energy use in either a hard or soft energy future. The total of the three ranges account for around 54% of all use for all years and both scenarios (except Business as Usual in 2025 where it is a fraction of a percentage point under 50%).

Electricity Specific

Electricity Specific uses[12] of energy tend to grow relatively, though not much absolutely, with time despite the high cost of electricity. As shown in Figures CA-4, CA-5, CA-7, and CA-8, electricity continues to find key uses in all sectors, and expands its role in some, notably Commercial and Transportation. In addition, as the use of electricity is gradually phased out of those uses where it is not needed or suited, non-thermal generating sources come to play a greater role, something that helps to explain the projected savings in the Energy Supply sector, as discussed just below. Thus, thermal sources (excluding nuclear), never so large in Canada as in most other countries, provided 22% of the electricity generated in 1978 but would be only 14% in 2000 and 9% in 2025 (Business as Usual scenario) as hydropower and other renewable sources replace them. Indeed, included in the figures for thermal generation are about 2 percentage points (10 to 12 PJ) each for peat-fired and wood-fired generation. In the provinces where such new thermal sources are developed, they generally replace existing oil-fired electricity. Even in 2025, the "ideal" soft energy sources of electricity, photovoltaics and wind taken together, still play comparatively small roles: 3% of electricity generation in 2025 in both scenarios. The shift from nonrenewable to renewable sources of electricity occurs in all provinces but is carried further in some than in others, as indicated in Table 3.20 and Figure 3.17.

The results in the Consumer Saturation scenario differ very little from those in the Business as Usual. In most cases, the share for renewables is slightly higher (notably so in New Brunswick), but in a couple of cases in the year 2000 it is lower as there is less need to bring on new capacity under the lower growth conditions of that scenario.

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[12] All figures in this section, it should be remembered, refer to purchased electricity. Electricity that is produced from waste products within an industrial subsector is not included. It should also be remembered that the definition of Electricity Specific in this study is very loose and in particular includes considerable Heating and Cooling energy.

TABLE 3.20

RENEWABLE ELECTRICITY AS A PERCENTAGE OF ELECTRICITY GENERATED
(Business as Usual Scenario)

	1978	2000	2025
Newfoundland	68	90	95
Nova Scotia	8	38	55
Prince Edward Island	0	56	100
New Brunswick	24	29	78
Quebec	99	100	100
Ontario	38	34	74
Manitoba	97	100	100
Saskatchewan	28	44	99
Alberta	10	47	100
British Columbia	96	92	95
Yukon Territory	88	98	99
Northwest Territory	58	86	91

Liquid Fuel

Apart from non-energy products (not shown on Figures CA-4, CA-5, CA-7, and CA-8), Liquid Fuel finds its key use in transportation. While holding its relative share of total use with time, the use of liquids gradually drops out of most other uses. If, for convenience, the total use of liquid forms of energy represented by the sum of refined petroleum products and biomass fluids, and if this sum is compared with the use of Liquid Fuel (which is defined to include only those uses that truly require a liquid), the "excess use" of liquids in the economy declines from about 60% in 1978 to 15% in 2000 and 10% in 2025. At the same time, the sources for obtaining it are diversified to some degree -- from total reliance on refined petroleum products to substantial reliance on biomass fluids but with a strong assist from natural gas (particularly in 2000), coal (in the marine subsector) and by continuing use of refined petroleum products (particularly in non-road modes). This diversification is supplemented by the use of electricity for some urban vehicles, urban transit and mainline railroads. Still, diversification is less here than in other quality categories; petroleum products may account for 100% of liquid fuel in 1978, but biomass fluids account for 90 to 93% in 2025. As has been indicated throughout this report, it is on this area that most future work needs to be focussed. Further discussion of the problems created by the shift to biomass fluids is deferred to Chapter 4.

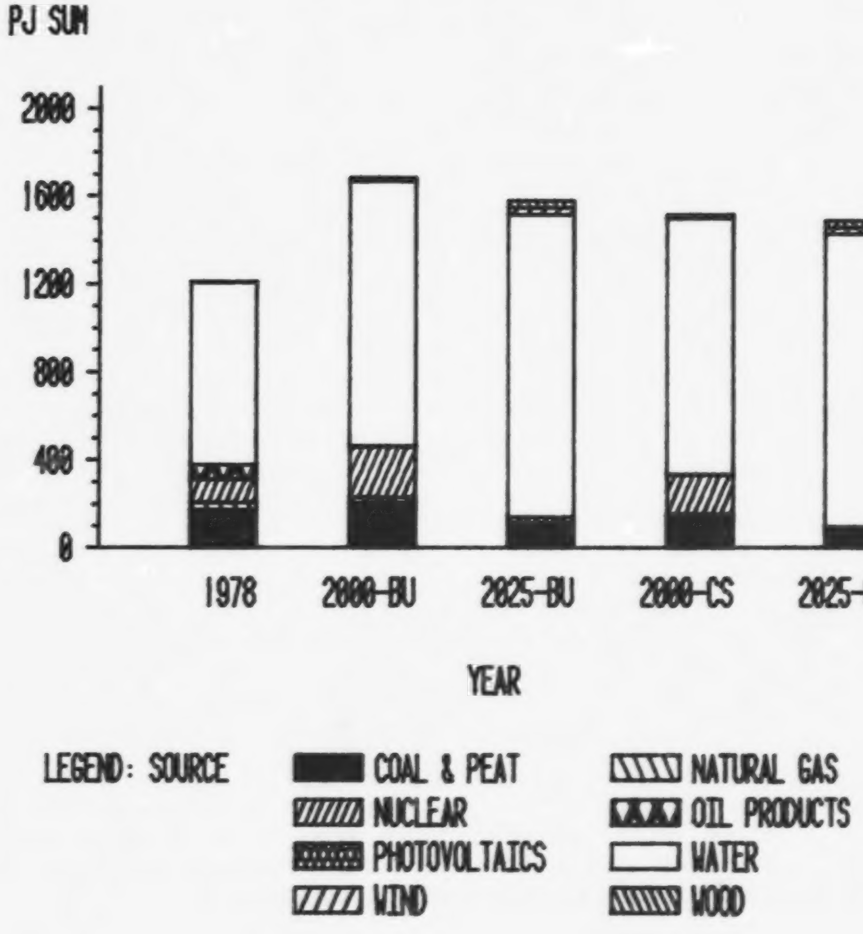
Non-Energy Products

Non-energy products include those sources and forms of energy used as material inputs, not as energy. For the purposes

FIGURE 3.17

PROJECTED ELECTRICITY PRODUCTION BY SOURCE

(PETAJOULES)



BU = BUSINESS AS USUAL SCENARIO

CS = CONSUMER SATURATION SCENARIO

of this study, they are most conveniently treated as a special quality category. While not a major component of the energy picture, it is essential to account for them statistically as the volume of energy they represent has to be included at the stage of primary production but does not appear at the stage of secondary use. Hence, non-energy products appear on Tables CA-2 and CA-12 through CA-15 but not on Tables CA-1 and CA-8 through CA-11.

There are three major non-energy products and a host of minor ones. Coke is used in large quantities in most steel making and other metal smelting processes. Oil and natural gas are used as inputs to make the plastics, fibres, resins and agricultural chemicals that are so much a part of today's world. And oil is also the source for asphalt, which appears as a major non-energy product in the construction industry. In addition to the big three, grease, lubricating oils, heat transfer oils and dozens of other products are made from energy raw materials.

For the purposes of this study, no direct attention was paid to the conservation of non-energy products. Rather, the quantities needed were determined by escalating usage according to the appropriate LTSM categories and then making the conservative assumption of 5% savings by the year 2000 and 10% savings by 2025. (Note that these savings refer to the energy materials as inputs; any energy used in the production of the non-energy products would be treated as energy use by the chemical industry.) There are several reasons why this approach should be conservative. First, use of several of the non-energy products is driven by LTSM projections that are probably too high; this is notably true for steel and hence for coke. Second, even if total use has not been overestimated, recycling possibilities have been ignored, something that is already important with lubricating oil and could become so with plastics and asphalt. Finally, substitutes, such as wood, natural fertilizers and mineral lubricants, could displace some of the non-energy products.

Ignoring those factors leads to the results shown on Tables CA-12 through CA-15. Comparing with Table CA-2, it can be seen that usage of non-energy products is projected to grow from around 540 petajoules in 1978 to 1160 in 2000 and to 1470 in 2025 in the Business as Usual scenario (830 and 1090 petajoules respectively in the Consumer Saturation scenario). Thus, their role increases with time. At the start they account for 9% as much energy as total secondary uses; at the end the figure is 27% (both scenarios; see Table 3.17 below).

The sources of non-energy products are not changed in the projections; they continue to be coal, natural gas and petroleum. However, in 1978, the sources for non-energy products were distributed as follows: 13% coal, 16% natural gas and 71% crude oil; by 2025 (Business as Usual) they would be: 12% coal, 35% natural gas and 53% crude oil. What is critical for the latter two is that instead of being minor uses, as in 1978, by 2025 non-energy uses have become the major remaining use for crude oil and one of the major remaining uses for natural gas. Non-energy uses account for 75 to 80% of crude and 45 to 55% of natural gas availability in 2025.

It has been suggested that biomass could be used as a substitute input for making petrochemicals (Palsson *et al*, 1981; Abelson, 1981). However, from the perspective of *this* report that suggestion merely transfers the problem from one energy source to another, and very possibly displaces petroleum from that use for which it is best suited, so it was not considered further.

Energy Supply Sector

The final step in any soft path analysis involves calculation of the energy requirements of the Energy Supply sector, that is of those parts of industry devoted to extracting, processing, converting and delivering energy for use. It includes *inter alia* the electricity, natural gas and refined petroleum products needed to extract, process and refine oil and gas; the natural gas needed to pump natural gas in pipelines; electrical losses for transmission and distribution of electricity; the Liquid Fuel (assumed to be methanol) needed to harvest and process biomass energy; and, in terms of primary energy, the conversion losses when a primary energy source is converted to a secondary form (biomass conversions or thermal generation of electricity).

The need for an Energy Supply sector reflects the fact that it takes energy to provide energy, and its position at the end of an analytic chain reflects the fact that the level of activity in the sector, hence its energy use, can only be determined after energy use in all other sectors has been determined. (This seems neater than it really is. Not only does it take energy to run the Energy Supply sector, it also takes energy to provide the energy needed by the Energy Supply sector, so one is really involved in an infinite chain of effects. Fortunately, the effects become negligible after a round or two.)

The size of the Energy Supply sector is shown in the five tables linking sources to uses (numbers CA-2 and CA-12 through CA-15) where it is represented by the sum of two columns. As detailed in Appendix 3.1, two columns are necessary because some of the energy is used in raw forms (hence appears on the left half of the tables with sources) and some is used in processed or converted forms (hence appears on the right side of the tables with products).

The Energy Supply sector is decidedly not negligible, as evidenced by a few examples from the provincial reports. In

British Columbia it is projected to account for one-third more energy than the Residential and Commercial sectors combined. In Saskatchewan the energy required to pump natural gas (most of which originates in Alberta) across the province is three times greater than that required by all coal mining and oil and gas drilling in the province. In Ontario the Energy Supply sector requires 1.1 exajoules (1100 petajoules) in 2000 and over 0.8 EJ in 2025, more than is required by the entire Industrial sector in the earlier year and just under its requirements in the later one. In 2000 half of the use is accounted for by losses of heat at nuclear power stations, but by 2025 over half is represented by losses in producing biomass fluids.

The role of the Energy Supply sector in the Canadian energy picture now and as projected can be brought out by comparing sectoral use with total secondary end use. It is convenient to show non-energy use in the same way, as shown in Table 3.21.

TABLE 3.21

ENERGY USED FOR THE ENERGY SUPPLY SECTOR
AND FOR NON-ENERGY PRODUCTS RELATIVE TO TOTAL SECONDARY USE

		Business as Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Total Secondary Use	100	100	100	100	100
Non-Energy Products	9	19	28	17	27
Energy Supply Sector[13]	23	41	43	41	46

Thus, from requiring less than one-quarter as much energy as secondary uses in 1978, the Energy Supply sector grows to require almost half as much. This reflects the shift to biomass energy sources, which have high energy supply requirements relative to oil and gas.

The composition of the Energy Supply sector also changes with time, as oil and gas become less important and as hydropower and solar electricity grow in share of electrical generation relative to thermal sources. The shift in thermal losses in the electricity subsector over time is particularly important. They account for 750 petajoules in 1978 (53% of sectoral use), climb to 990 petajoules (but only 39% of sectoral use) in 2000 and then drop to 280 petajoules (12% of sectoral use) in

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[13] Includes energy used in raw and processed forms.

2025. These figures are for the Business as Usual scenario; the shares are roughly the same in Consumer Saturation. As suggested above, the great losses in 2025 are represented by methanol use (mainly for the conversion of biomass to methanol, which accounts for nearly 60% of Energy Supply sector use in both scenarios.)

3.6 ENERGY FLOWS IN 2000 AND 2025

One of the general objectives of a soft energy path is to develop decentralized sources of energy appropriate to regional and local conditions. This normative thrust is given added weight by the low energy density of numerous renewable energy sources, such as wood or solar heat, which means that they cannot economically be transported very far, if at all. Thus, in contrast to today's shipments of oil, gas and electricity for space heating, cost-effectiveness criteria in a soft path dictate that Heating and Cooling energy be derived very largely from internal soures (i.e., by the prevention of heat losses) in residences and from the capture and redistribution of waste heat in industry.

As a partially unintended result of the thrust toward decentralization, soft paths tend toward national, regional and even local self-reliance. This effect is illustrated in Figures 3.18 through 3.22, which show the changes in net energy trade[14] among Canadian provinces and in national imports and exports of coal, crude oil, natural gas, electricity and biofluids by scenario and year.

With very few exceptions the figures show a decreasing movement of energy across provincial or national borders. (Results from the two scenarios are quite similar with smaller flows occurring in the Consumer Saturation than in the Business as Usual scenario.) In the case of crude oil, this is simply a result of declining resource availability, but in most cases it is a result of the gradually diminishing need in each province for energy resources from other provinces. Of two exceptions only one involves energy per se (the increased trade in coal is mainly for coke used as a non-energy product). The other is real; by the year 2000 biomass fluids have become an energy form important enough to move from provinces with a biomass surplus to those with a deficit. However, total trade never comes close to rivaling the scale of today's shipments of natural gas or

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[14] The word "net" as used here means that in cases where energy moves in both directions across a border, only the net flow is shown.

FIGURE 3.18

MAJOR INTERNATIONAL AND INTERPROVINCIAL FLOWS OF COAL AND PEAT IN CANADA BY SCENARIO AND YEAR

Notes: See Appendix 3.1. Imports and exports of coking coal underlined.

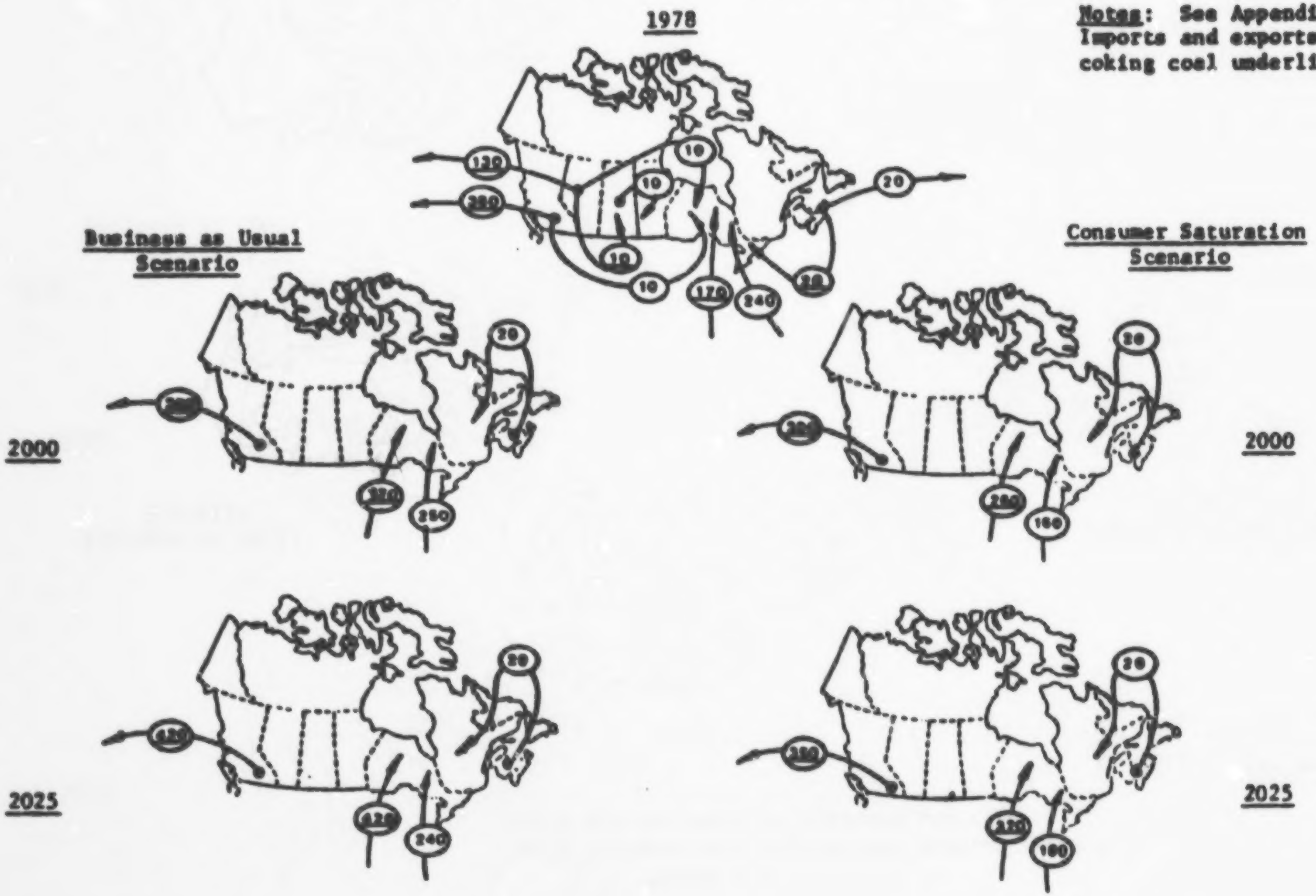

1978
120
280
10
10
10
10
170
240
20
20
Business as Usual Scenario
2000
20
320
250
2025
20
420
420
240
Consumer Saturation Scenario
2000
20
280
280
180
2025
20
380
330
180

FIGURE 3.19
MAJOR INTERNATIONAL AND INTERPROVINCIAL FLOWS OF
CRUDE OIL IN CANADA BY SCENARIO AND YEAR

Notes: See Appendix 3.1.

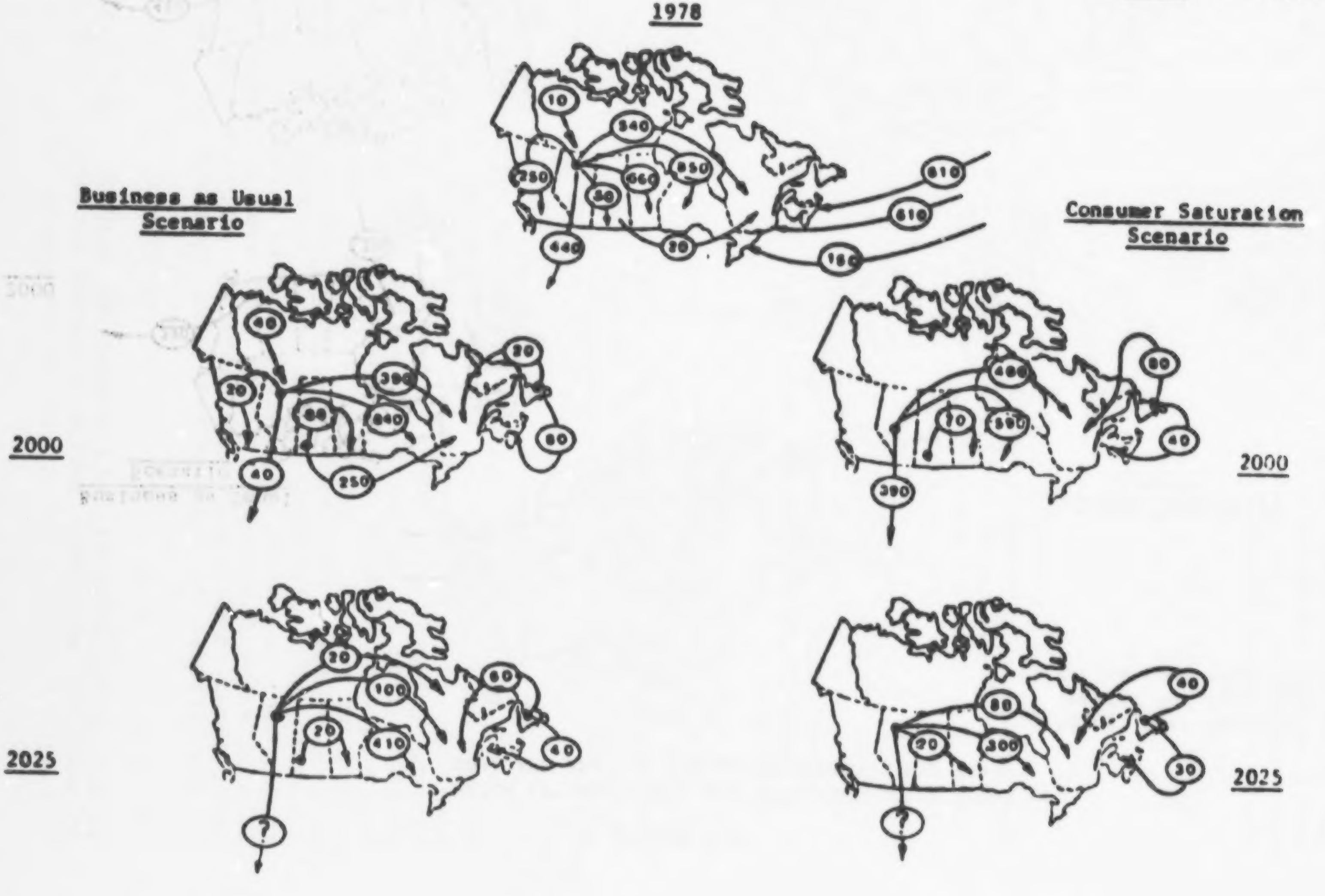

1978
10
340
250
50
660
850
440
20
610
610
180
Business as Usual
Scenario
2000
40
20
390
80
840
40
250
20
80
2025
20
100
20
410
60
40
?
Consumer Saturation
Scenario
2000
400
70
390
80
40
390
2025
80
20
300
40
30
?

FIGURE 3.20

MAJOR INTERNATIONAL AND INTERPROVINCIAL FLOWS OF NATURAL GAS IN CANADA BY SCENARIO AND YEAR

Notes: See Appendix 3.1.
Assumes exports from Quebec, Ontario and Manitoba originate in Alberta; shipments from Alberta to British Columbia are assumed to be exported.

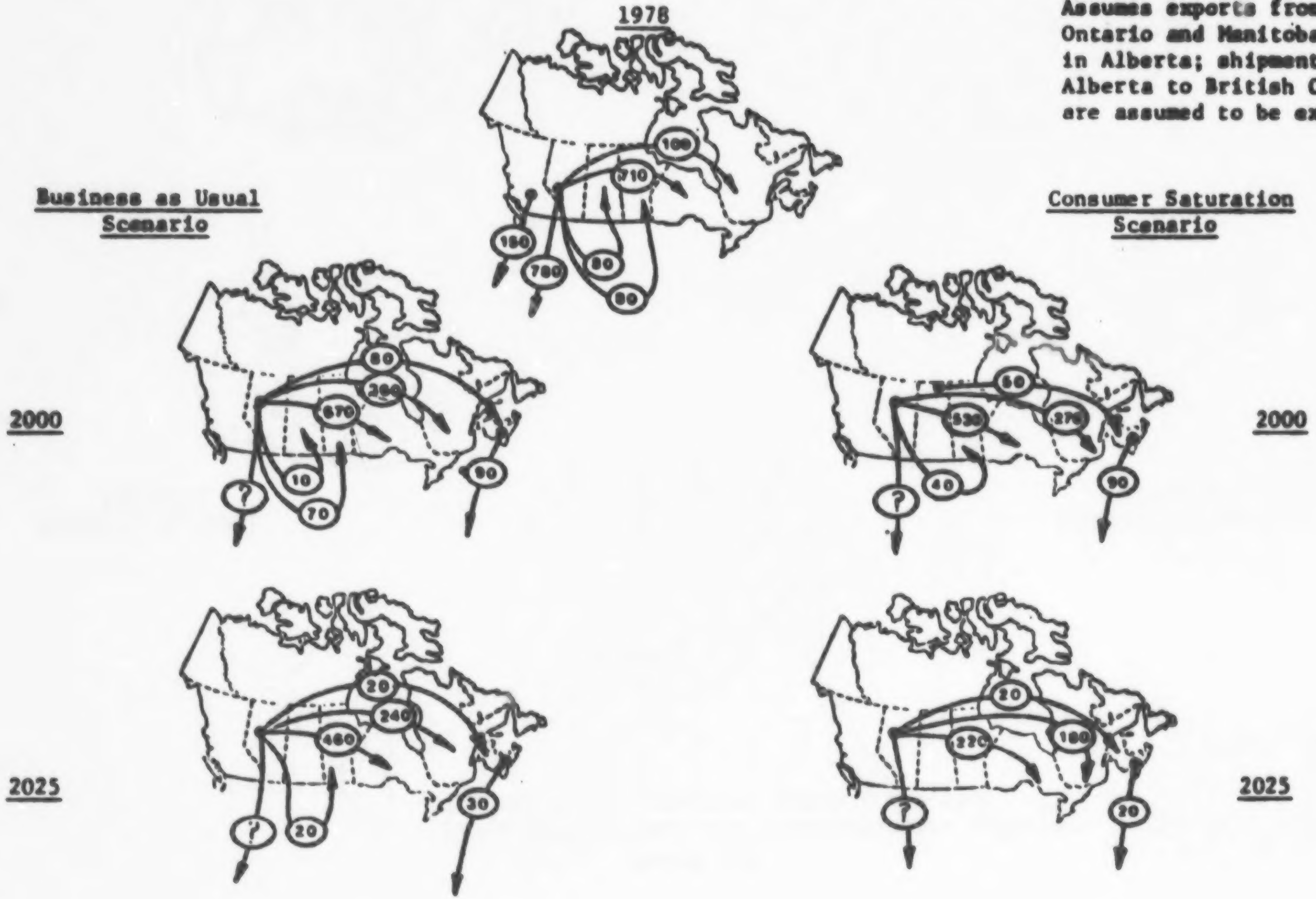

1978
100
710
150
780
80
80
Business as Usual Scenario
Consumer Saturation Scenario
2000
80
290
570
10
70
?
90
50
530
270
40
?
90
2000
2025
20
240
460
20
?
30
20
220
180
?
20
2025

FIGURE 3.21
MAJOR INTERNATIONAL AND INTERPROVINCIAL FLOWS OF ELECTRICITY IN CANADA BY SCENARIO AND YEAR

Notes: See Appendix 3.

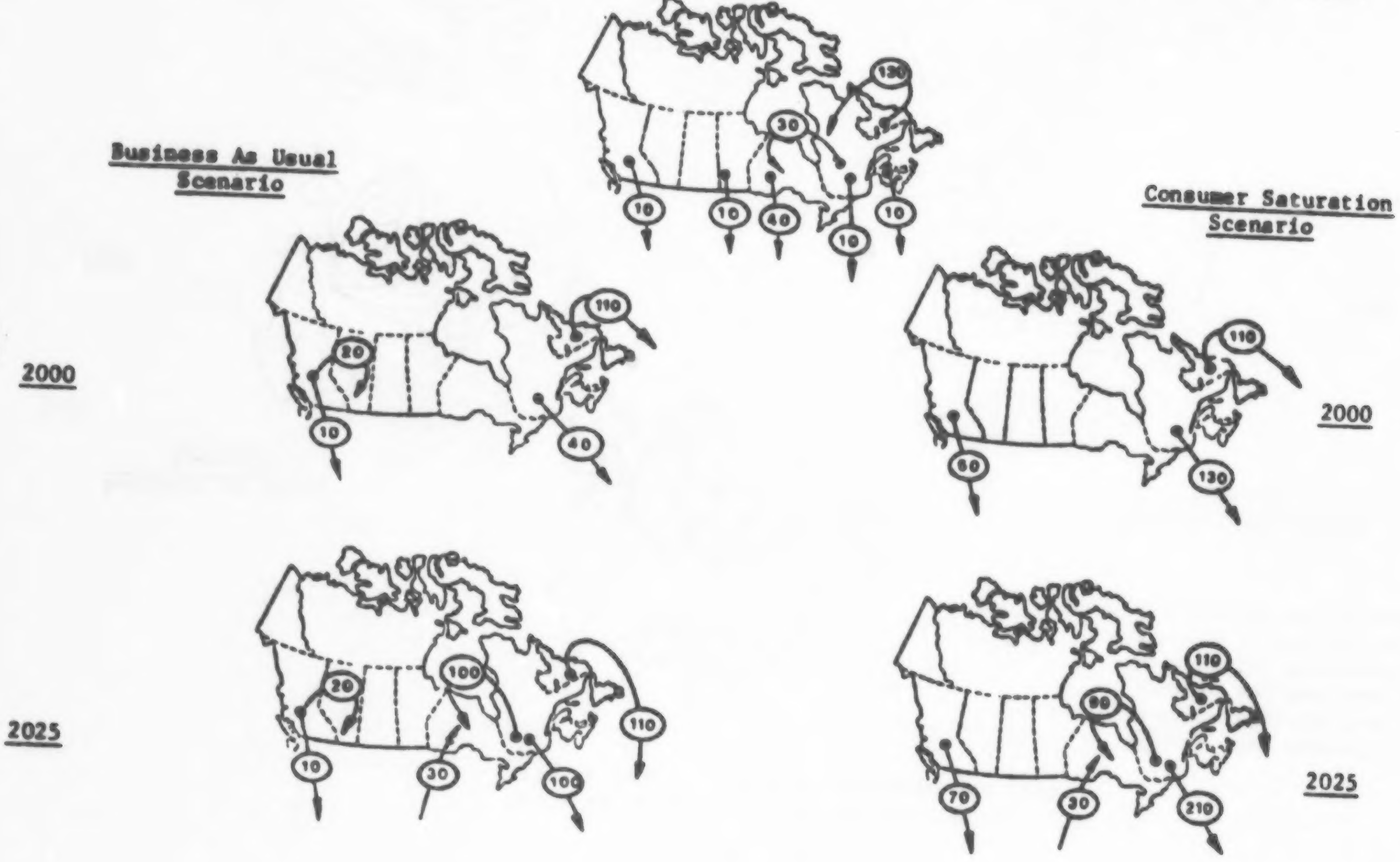
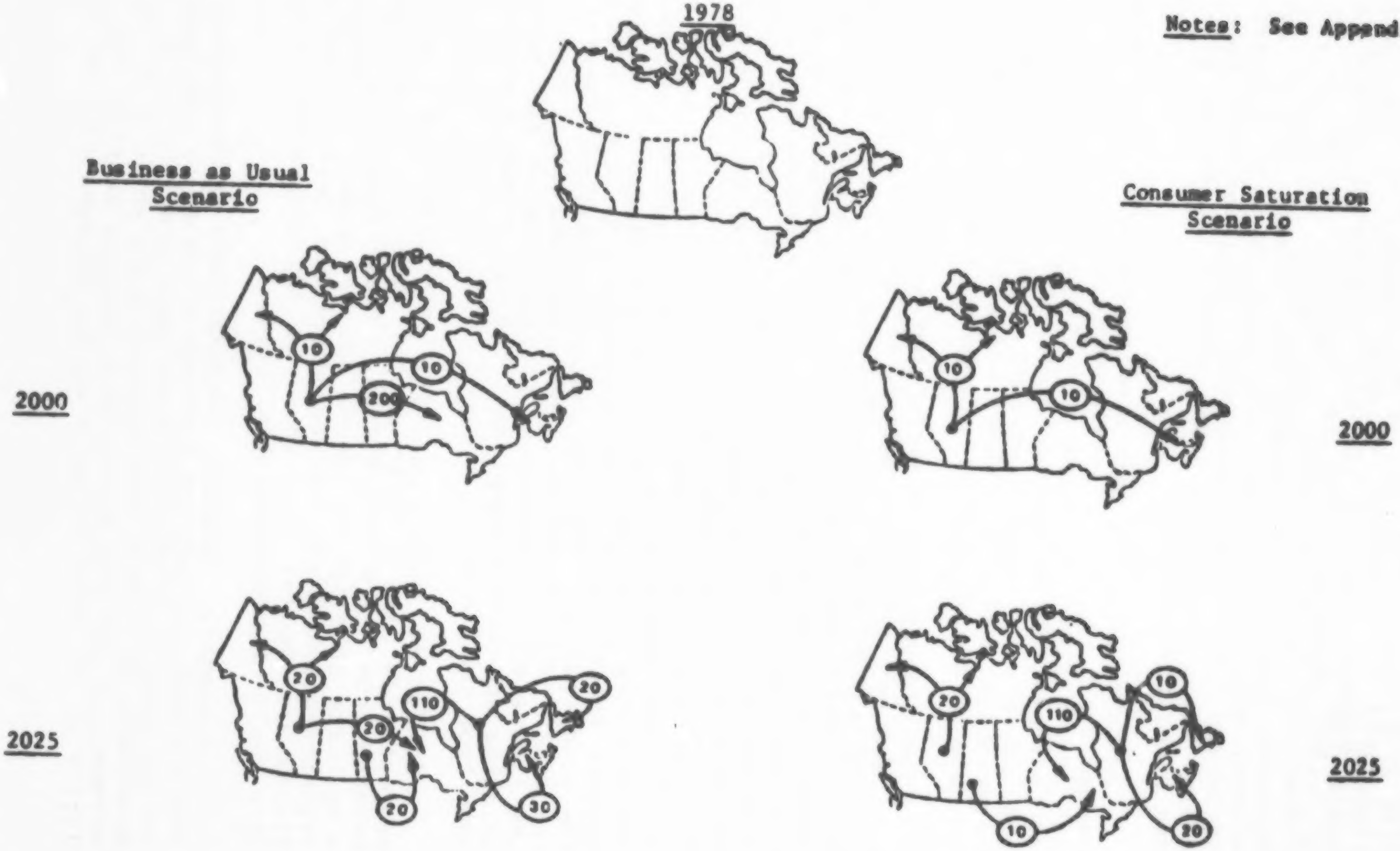

1978
130
30
10
10
40
10
10
Business As Usual Scenario
2000
110
20
10
40
2025
100
20
110
10
30
100
Consumer Saturation Scenario
2000
110
60
130
2025
110
90
70
30
210

FIGURE 3.22

MAJOR INTERNATIONAL AND INTERPROVINCIAL FLOWS OF BIOMASS FLUIDS IN CANADA BY SCENARIO AND YEAR


1978
Business as Usual Scenario
Consumer Saturation Scenario
2000
10
10
200
2000
10
10
2025
20
110
20
20
20
30
2025
20
110
10
10
20

Notes: See Appendix 3.1.

crude oil. Moreover, the level and specific directions of the inter-provincial trade in biomass fluids are a direct result of assumptions with respect to developments in the Canadian oil supply subsector and in the alcohol-powered automobile subsector. For example, given the specific course of development assumed for Newfoundland (i.e., major offshore fields being developed sequentially rather than simultaneously but no new refinery being constructed), the province will both export crude and import RPPs; also, given the likelihood that some alcohol-powered vehicles will be used, biomass fluids are also imported from other provinces.

In some cases the indicated interprovincial flows of energy stemmed from social or environmental choices pursuant to soft path objectives. For example, Ontario has a number of options for hydroelectric developments on north-flowing rivers, but they were deemed to involve serious conflicts with environmental preservation and with native land claims. Instead, the choice was made to import surplus hydropower from Quebec.

The figures show clearly that imports of energy into Canada, and any attendant balance of payments effects, would be greatly reduced under either Business as Usual or Consumer Saturation conditions. On the other hand, energy exports could be larger. Soft paths do not aim for self-sufficiency as an objective but only use it as a working hypothesis. There is no inherent objection to energy trade when full replacement costs are paid and when the production, processing and transportation do not violate environmental or social objectives. Thus, natural gas exports from Alberta are left open in the diagrams, as they do not appear to be environmental problems or resource limitations over the time frame of our study. The figures even suggest renewed exports of high-cost oil in the second half of the study period (even earlier under Consumer Saturation). On the other hand, there would be great hesitation about expanding the hydroelectric system or growing biomass for export. Only existing and likely surpluses from the former are indicated and none from the latter.

So far as imports go, the only significant energy import projected for the future is coal (both coking and steam) into Ontario from the United States. These imports do not stem from a resource shortage in Canada but are simply a recognition that transportation links between southern Ontario and U.S. coal fields are shorter than those to any provinces in Canada that have coals of comparable qualities.

In summary, Canada's international balance of trade would improve under either the Business as Usual or the Consumer Saturation scenario. Within Canada each province would become substantially more self-sufficient. There would still be plenty of movement of energy, mainly from biomass sources, but relatively little of it would cross a border because none of it could be transported any great distance. With the exception of biomass fluids, new flows turn out mainly to represent a choice to minimize environmental impacts. However, the growth of shipments of biomass fluids does indicate, once again, that the development of an alternative transportation fuel is the most difficult problem within the soft path framework.

FIGURE CA - 1

ENERGY END-USES AND FORMS IN CANADA IN 1978

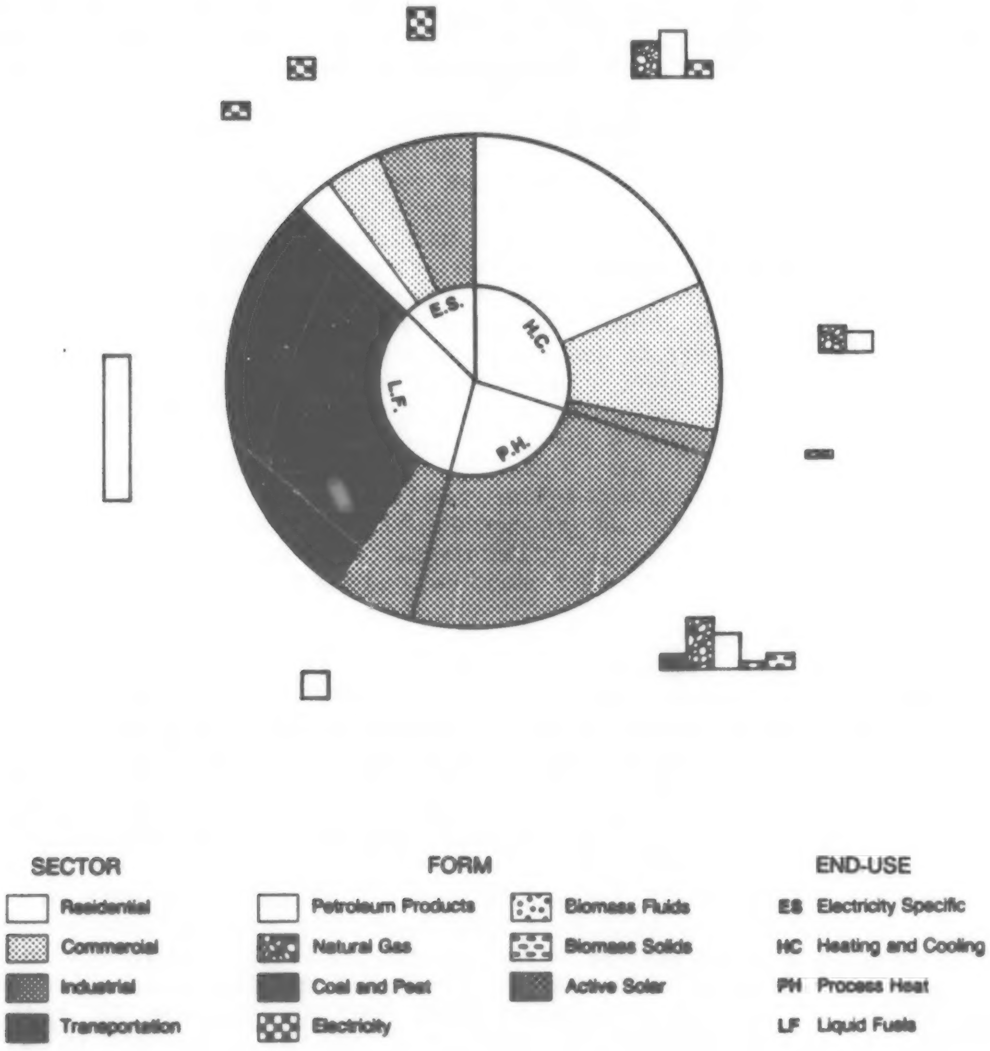


FIGURE CA-2

RELATIVE DEMOGRAPHIC, ECONOMIC AND ENERGY GROWTH IN CANADA, 1978 TO 2025

(1978=100)

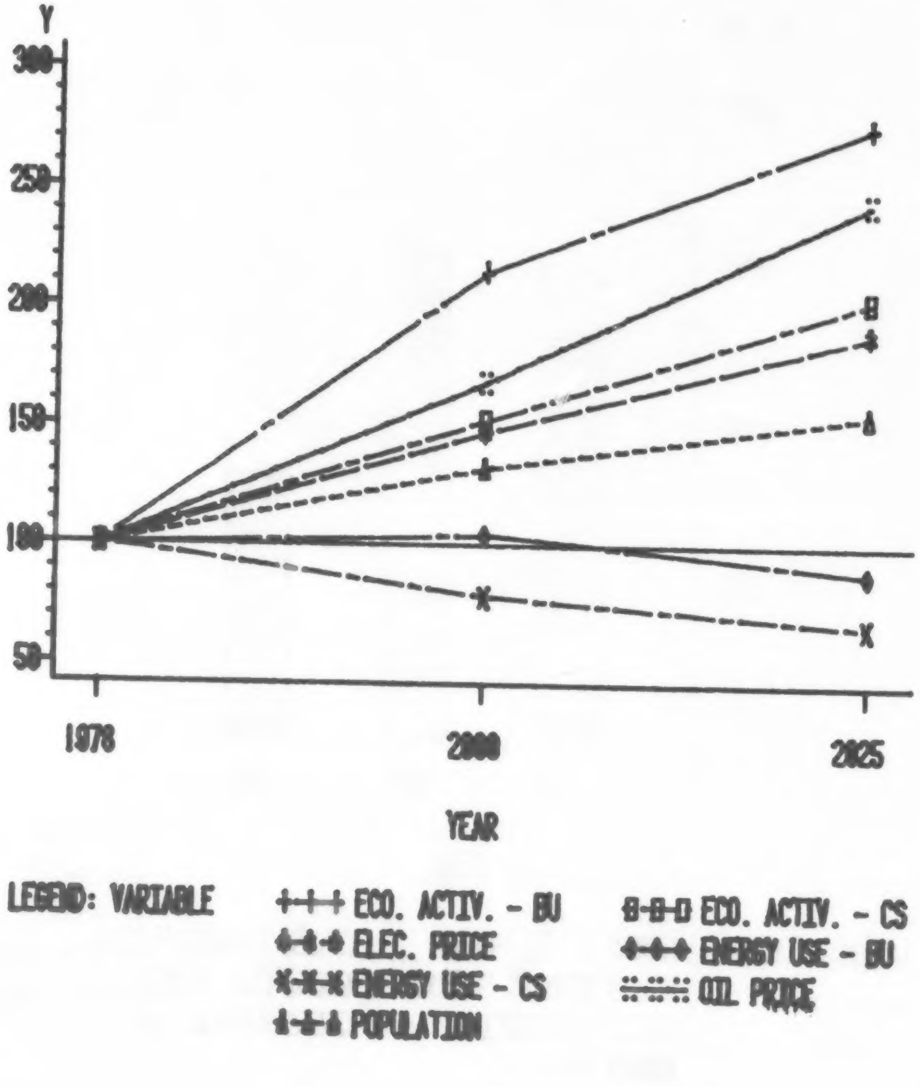


FIGURE CA-3
SECONDARY ENERGY USE IN CANADA BY FORM, BUSINESS AS USUAL SCENARIO
(PETAJOULES)

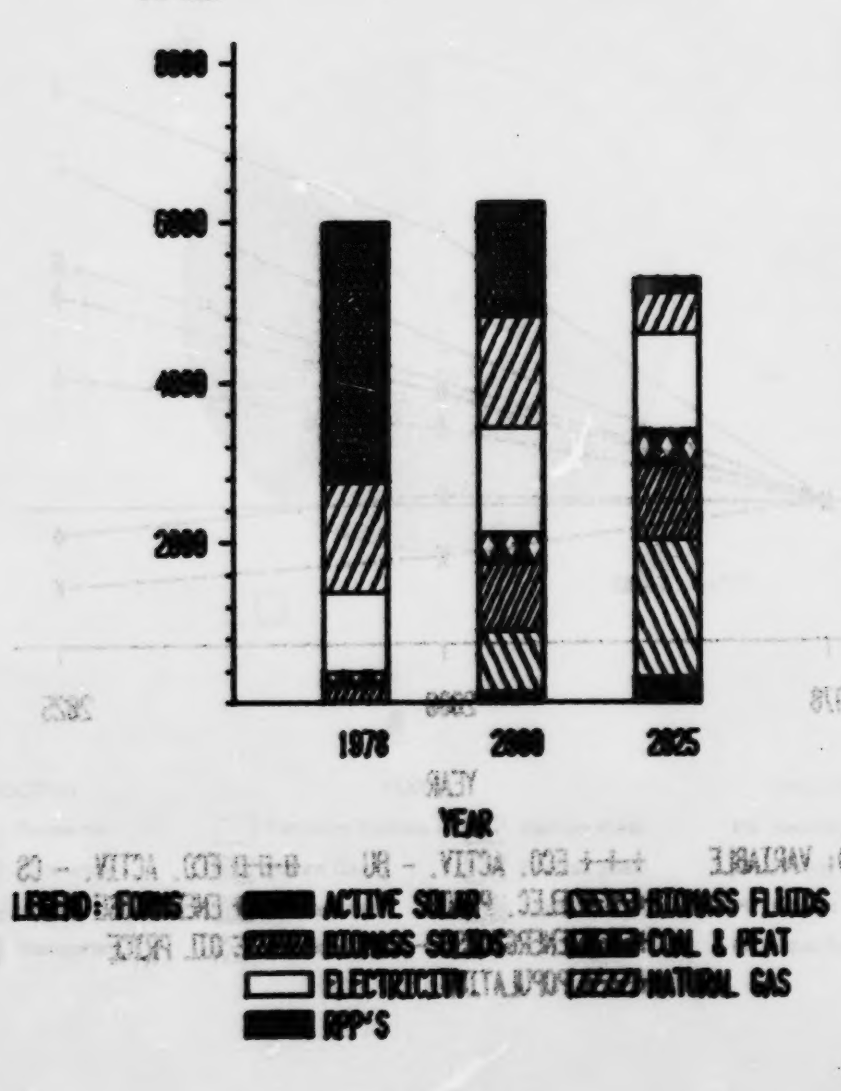


FIGURE CA - 4
ENERGY END-USES AND FORMS IN CANADA IN 2000 – BU SCENARIO

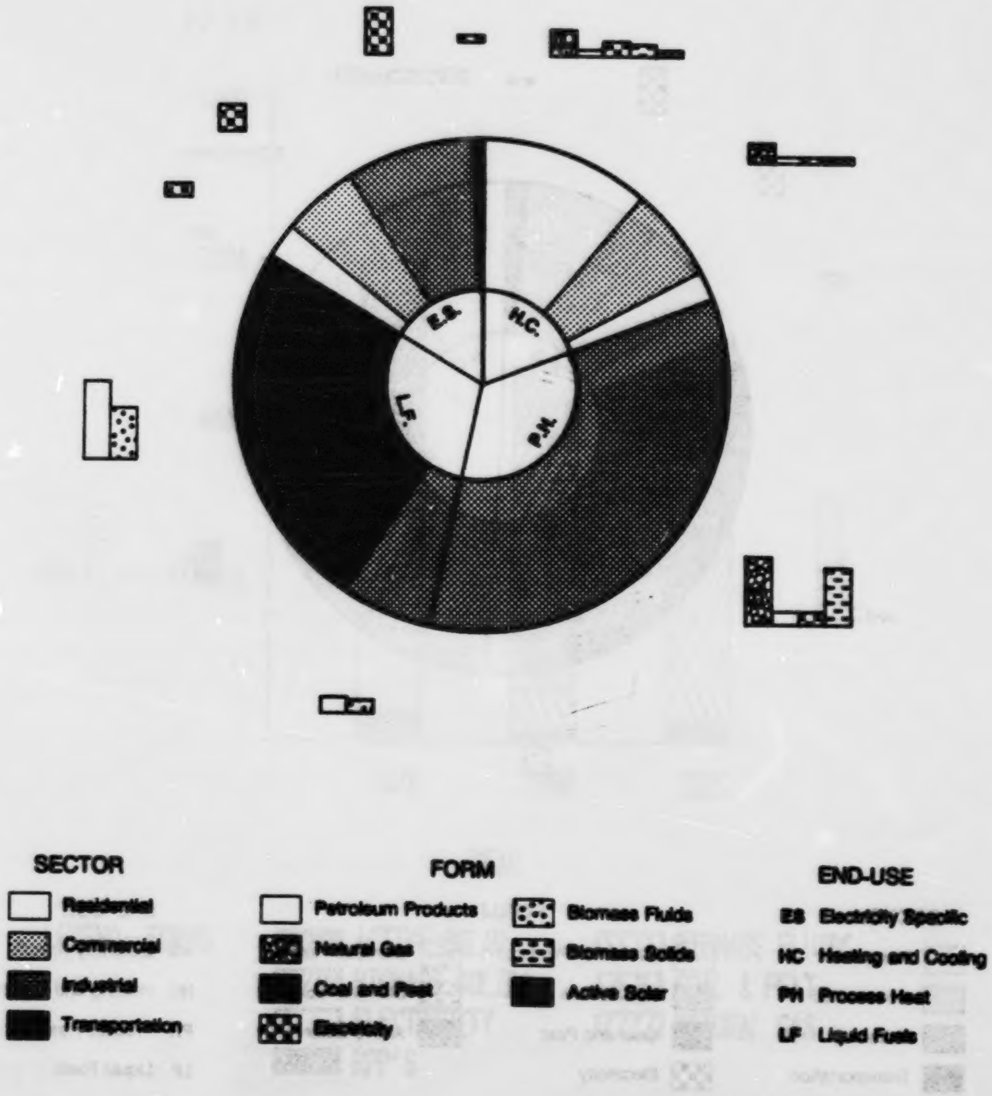


FIGURE CA - 5

ENERGY END-USES AND FORMS IN CANADA IN 2025 – BU SCENARIO

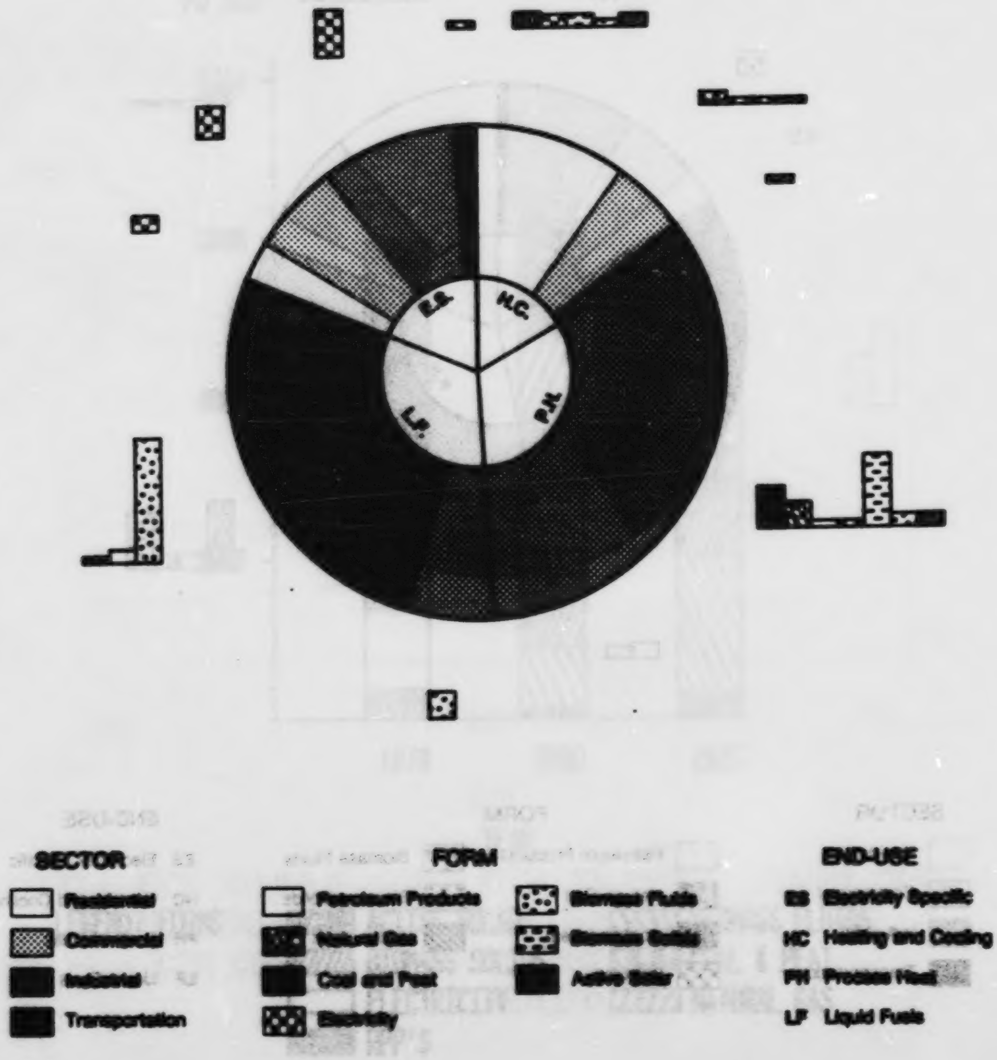


FIGURE CA-6

SECONDARY ENERGY USE IN CANADA BY FORM, CONSUMER SATURATION SCENARIO (PETAJOULES)

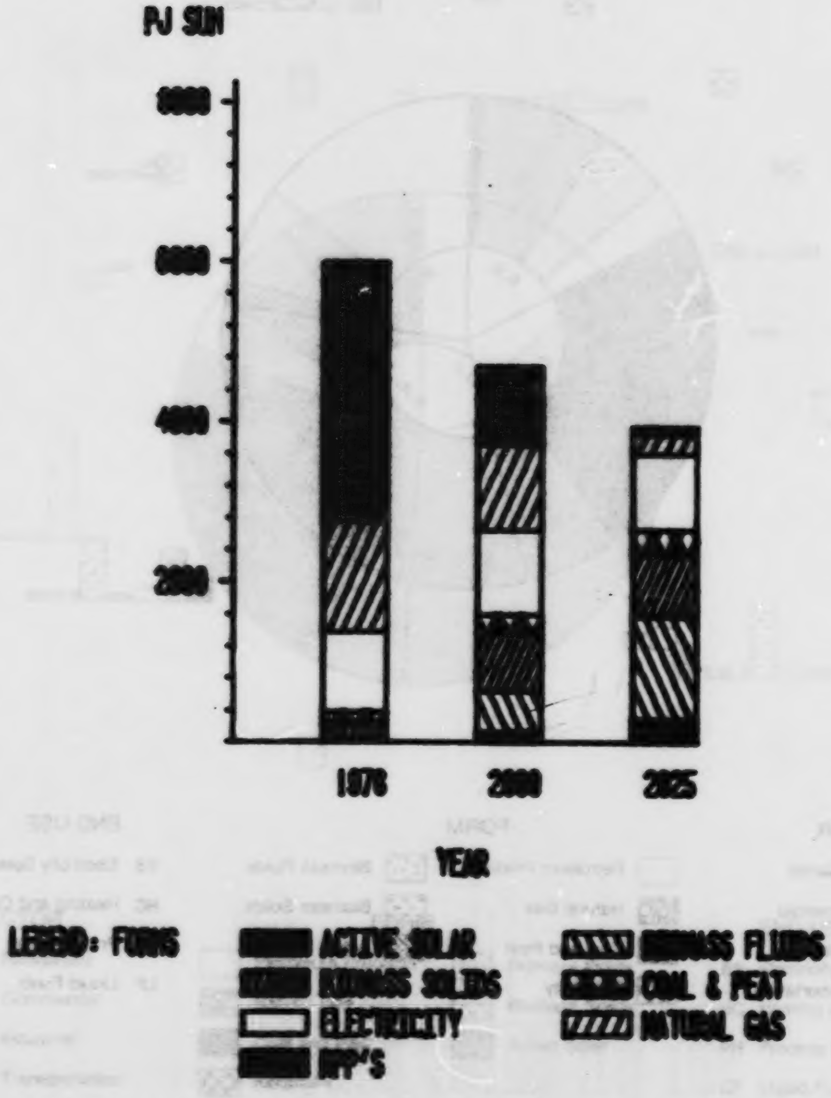


FIGURE CA - 7
ENERGY END-USES AND FORMS IN CANADA IN 2000 – CS SCENARIO

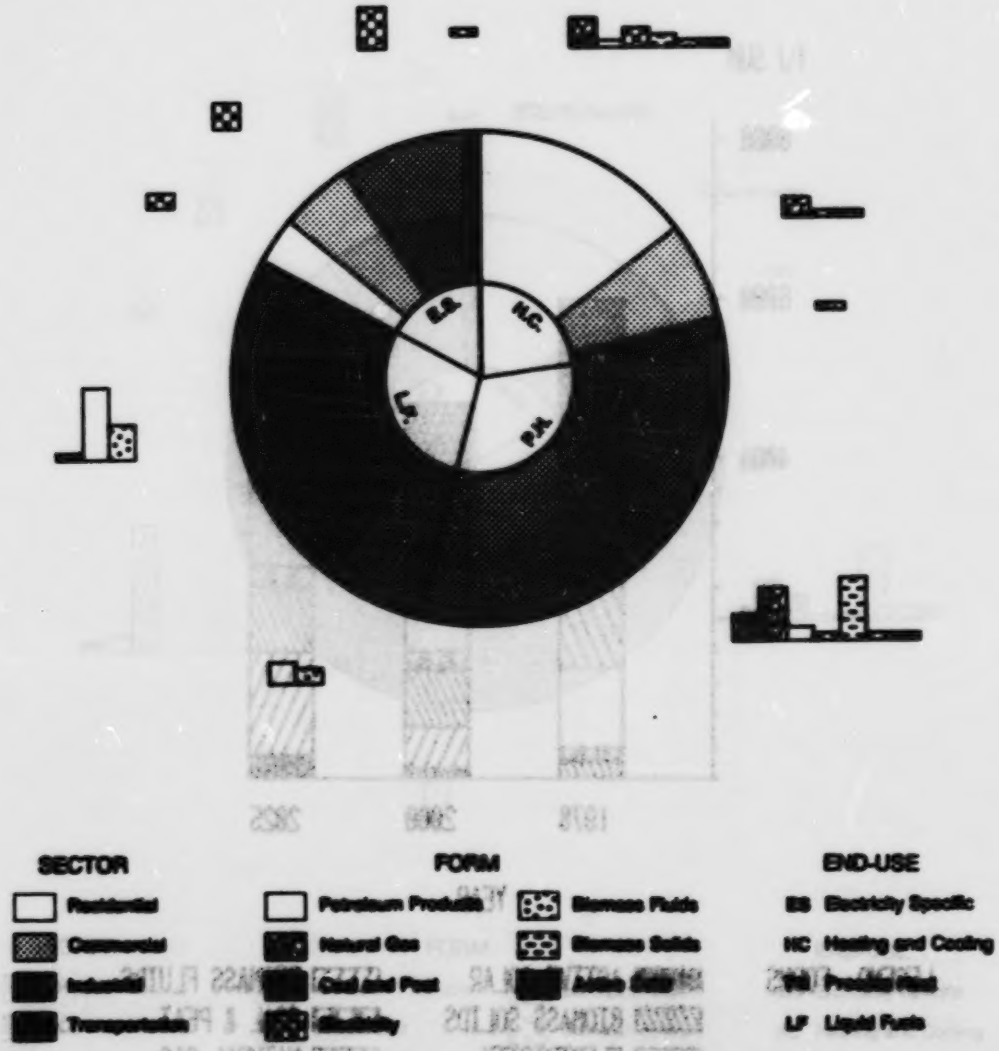


FIGURE CA - 8
ENERGY END-USES AND FORMS IN CANADA IN 2025 – CS SCENARIO

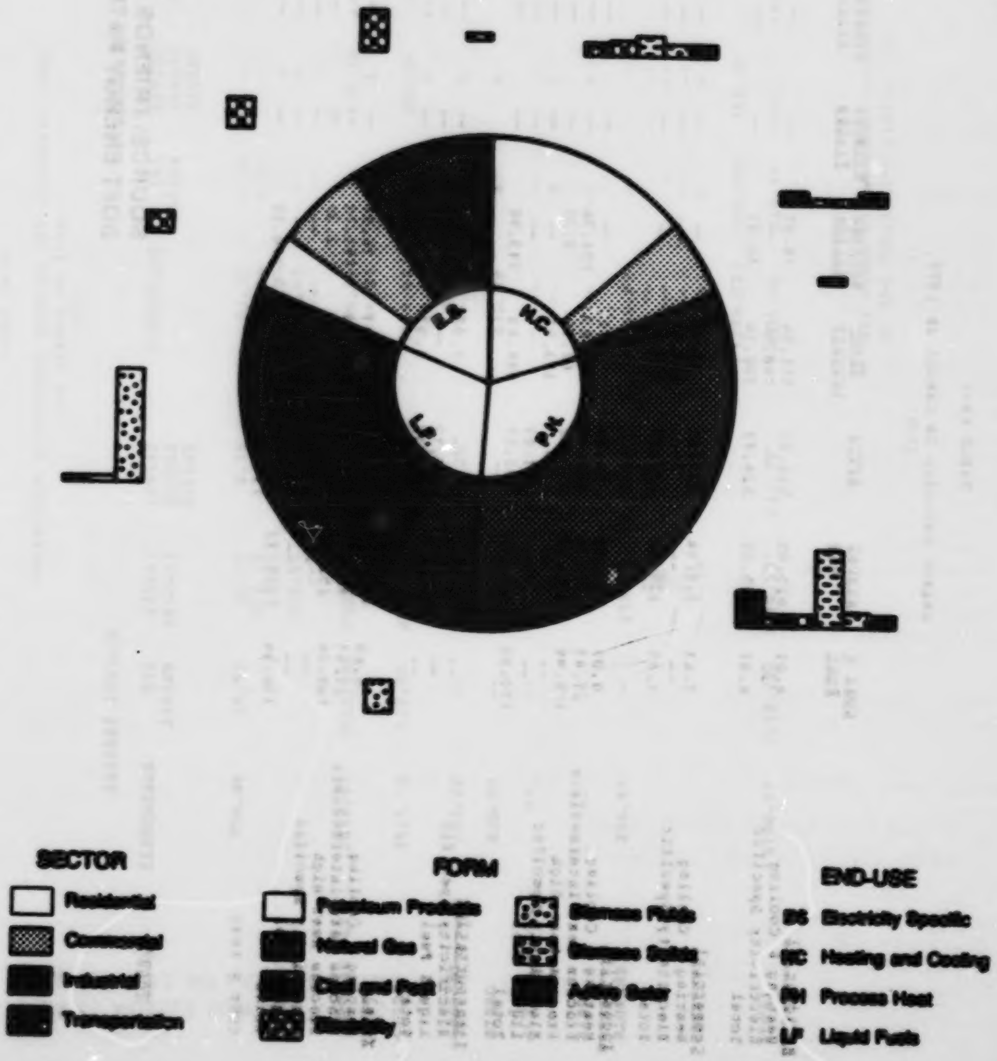


TABLE CA-1

ENERGY END-USES IN CANADA IN 1978
(PJ)

	Coal & Coke	Natural Gas	RPP's	Elec-tricity	Biomass Solids	Biomass Fluids	Active Solar	Total
Residential								
Heating & Cooling	4.01	425.05	524.73	151.54	16.91	--	--	1122.24
Electricity Specific	--	--	--	148.56	--	--	--	148.56
Total	4.01	425.05	524.73	300.10	16.91	--	--	1270.80
Commercial								
Heating & Cooling	1.61	321.14	237.37	25.47	--	--	--	585.59
Electricity Specific	--	--	--	220.48	--	--	--	220.48
Total	1.61	321.14	237.37	245.95	--	--	--	806.07
Industrial								
Heating & Cooling	0.07	36.58	54.96	1.10	--	--	--	92.71
Process Heat-Intermediate	21.41	329.56	229.98	10.83	191.70	--	--	783.16
Process Heat-High	149.44	252.00	196.62	63.75	2.20	--	--	664.41
Electricity Specific	--	--	--	373.81	--	--	--	373.81
Liquid Fuel	--	--	311.99	--	--	--	--	311.99
Total	170.92	618.14	793.55	449.49	193.90	--	--	2226.00
Transportation								
Electricity Specific	--	--	--	1.93	--	--	--	1.93
Liquid Fuel	--	--	1688.12	--	--	--	--	1688.12
Total	--	--	1688.12	1.93	--	--	--	1690.05
Totals								
Heating & Cooling	5.69	782.77	817.06	178.11	16.91	--	--	1800.54
Process Heat-Intermediate	21.41	329.56	229.98	10.83	191.70	--	--	783.16
Process Heat-High	149.44	252.00	196.62	63.75	2.20	--	--	664.41
Electricity Specific	--	--	--	744.78	--	--	--	744.78
Liquid Fuel	--	--	2000.11	--	--	--	--	2000.11
Total	176.54	1364.33	3243.77	997.47	210.81	--	--	5993.00

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-2

PRODUCTION OF PRIMARY SOURCES AND SECONDARY FORMS IN CANADA IN 1976 (PJ)

	PRIMARY SOURCES				SECONDARY FORMS					
SOURCE	Production	Net Inflow	Availability	Energy Supply Sector	Production	Net Inflow	Energy Supply Sector	Non-Energy Use	Energy Use	FORM
COAL & PEAT	754.06	25.97	60.25	0.15	52.10	1.00	--	--	53.10	COAL & PEAT
			157.74	13.06	144.26	0.92	--	68.95	76.23	COKE
			51.63	4.42	47.21	--	--	--	47.21	COKE OVEN GAS
			510.41	344.90	173.43	*	*	*	*	ELECTRICITY
			--	--	--	--	--	--	--	METHANOL
NATURAL GAS	2611.97	(923.70)	1592.94	2.21	1590.33	--	137.20	88.80	1364.33	NATURAL GAS
			95.67	60.06	34.81	*	*	*	*	ELECTRICITY
CRUDE	3441.10	427.50	4683.77	54.13	3629.64	207.42	286.94	306.35	3243.77	RPP's
			165.00	102.19	62.81	*	*	*	*	ELECTRICITY
URANIUM	383.20	--	383.20	267.20	106.00	*	*	*	*	ELECTRICITY
HYDRO	830.09	--	830.09	--	830.09	*	*	*	*	ELECTRICITY
ACTIVE SOLAR	--	--	--	--	--	--	--	--	--	ACTIVE SOLAR
			--	--	--	*	*	*	*	ELECTRICITY
WIND	--	--	--	--	--	*	*	*	*	ELECTRICITY
BIOMASS	210.09	--	214.75	3.06	210.09	--	--	--	210.09	BIOMASS SOLIDS
			--	--	--	--	--	--	--	METHANOL
			--	--	--	--	--	--	--	VEGETABLE OIL
			--	--	--	--	--	--	--	BIOGAS
			3.74	0.31	3.43	*	*	*	*	ELECTRICITY
					(1210.57)	(64.80)	148.30	--	997.47	TOTAL ELECTRICITY
TOTAL	8100.99	(470.20)	7718.79	833.79	6885.00	144.54	527.44	464.10	5993.00	TOTAL

* All flows of secondary electricity are shown on the Total Electricity line.

SOURCE: FRIENDS OF THE EARTH SOFT ENERGY PATH STUDY 1983

TABLE CA-3

DEMOGRAPHIC AND ECONOMIC ACTIVITY IN CANADA

		Business As Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
POPULATION (000's)	23 315	30 943	36 915	30 943	36 915
HOUSEHOLDS (000's)	7876.7	11244.4	14187.7	11244.4	14187.7
Single Family Detached	4861.1	5989.6	7021.4	5984.0	7009.7
Attached Housing	854.6	1465.4	2257.7	1468.0	2263.1
Apartments	2008.3	3520.3	4559.7	3523.3	4565.7
Mobile Homes	152.7	269.1	348.9	269.1	349.2
ECONOMIC ACTIVITY (000 000 000's 1980$)	460.5	980.5	1264.6	692.4	920.4
Agriculture	19.7	30.1	35.7	26.3	32.2
Mining	26.6	51.6	65.4	37.2	44.3
Pulp and Paper	23.3	55.5	74.2	37.9	45.0
Primary Metals	29.0	66.4	87.0	46.2	59.6
Food Processing	28.9	45.7	56.4	41.1	51.7
Chemicals	10.3	22.8	28.8	15.9	21.1
Construction	51.7	90.9	110.0	70.9	91.0
Other Industrial	111.1	248.5	318.3	170.0	235.8
Commercial Transportation	17.8	42.4	55.7	28.6	37.6
Commercial Sector (excluding government)	142.1	326.6	433.1	218.3	302.1
GROSS DOMESTIC PRODUCT (GDP) (000 000 000's 1980$)	257.2	649.1	840.1	451.1	619.8
GDP/capita (1980$)	10 960	20 980	22 770	14 580	16 800

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-4

RESIDENTIAL ENERGY USE IN CANADA
(PJ)

SUBSECTOR		Business As Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Single Family Detached					
Heating & Cooling	753.82	429.37	299.09	423.74	298.95
Electricity Specific	85.41	78.44	69.93	78.40	69.87
Total	839.23	507.81	369.02	502.14	368.82
Attached Housing					
Heating & Cooling	116.96	77.43	74.90	77.20	75.71
Electricity Specific	18.07	18.09	19.41	17.75	19.35
Total	129.03	95.52	94.31	94.95	95.06
Apartments					
Heating & Cooling	236.72	170.96	138.60	170.66	139.26
Electricity Specific	41.96	42.82	49.82	42.72	49.82
Total	278.68	213.78	188.42	213.38	189.08
Mobile Homes					
Heating & Cooling	20.74	19.11	18.34	18.96	19.07
Electricity Specific	3.12	3.08	3.26	3.06	3.24
Total	23.86	22.19	21.60	22.02	22.31
Totals					
Heating & Cooling	1122.24	696.87	530.93	690.56	532.99
Electricity Specific	148.56	142.43	142.42	141.93	142.28
Total	1270.80	839.30	673.35	832.49	675.27

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-5

COMMERCIAL ENERGY USE IN CANADA
(PJ)

SUBSECTOR		Business As Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Offices					
Heating & Cooling	47.13	29.89	17.61	24.51	12.83
Electricity Specific	20.72	40.85	47.46	26.16	31.72
Total	67.85	70.74	65.07	50.67	44.55
Schools & Universities					
Heating & Cooling	86.30	46.31	33.82	39.55	27.20
Electricity Specific	23.45	32.77	31.71	26.43	26.39
Total	109.75	79.08	65.53	65.98	53.59
Hospitals					
Heating & Cooling	69.55	44.07	27.40	36.79	23.23
Electricity Specific	14.03	21.73	24.18	19.40	21.56
Total	83.58	65.80	51.58	56.19	44.79
Retail					
Heating & Cooling	80.63	60.64	38.52	40.13	26.43
Electricity Specific	44.95	49.66	50.52	34.68	34.06
Total	125.58	110.30	89.04	74.81	60.49
Hotels & Motels					
Heating & Cooling	30.52	18.75	12.35	14.63	9.84
Electricity Specific	8.68	17.66	19.70	10.55	12.90
Total	39.20	36.41	32.05	25.18	22.74
Restaurants					
Heating & Cooling	18.99	11.78	8.87	10.28	6.13
Electricity Specific	11.01	11.57	11.96	8.34	8.45
Total	30.00	23.35	20.83	18.62	14.58
Government					
Heating & Cooling	57.54	41.35	28.05	33.02	21.72
Electricity Specific	22.57	26.19	24.87	22.28	18.27
Total	80.11	67.54	52.92	55.30	39.99
Street Lighting					
Electricity Specific	4.93	4.48	4.07	4.30	3.91
Unallocated					
Heating & Cooling	194.93	130.26	106.18	102.97	68.57
Electricity Specific	70.14	98.27	87.21	69.69	68.14
Total	265.07	228.53	193.39	172.66	136.71
Totals					
Heating & Cooling	585.59	383.05	272.80	301.88	195.95
Electricity Specific	220.48	303.18	301.68	221.83	225.40
Total	806.07	686.23	574.48	523.71	421.35

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-6

INDUSTRIAL ENERGY USE IN CANADA
(PJ)

SUBSECTOR		Business As Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Agriculture					
Heating & Cooling	20.48	19.46	17.59	16.64	15.22
Process Heat-Intermediate	0.02	0.05	0.05	0.04	0.04
Electricity Specific	10.00	11.90	10.57	10.31	9.58
Liquid Fuel	134.29	130.98	117.51	114.75	107.18
Total	164.79	162.39	145.72	141.74	132.02
Forestry					
Heating & Cooling	0.01	0.02	0.02	0.01	0.01
Process Heat-Intermediate	0.36	0.37	0.20	0.32	0.18
Electricity Specific	0.25	0.26	0.19	0.22	0.17
Liquid Fuel	26.43	26.76	16.93	20.57	11.73
Total	27.05	27.41	17.34	21.12	12.09
Fishing/Hunting/Trapping					
Liquid Fuel	13.62	13.70	9.79	11.46	8.98
Total	13.62	13.70	9.79	11.46	8.98
Iron Mines					
Heating & Cooling	0.49	0.87	0.83	0.59	0.50
Process Heat-Intermediate	11.49	20.05	19.92	14.33	11.67
Process Heat-High	17.20	30.41	30.05	21.05	17.48
Electricity Specific	20.13	28.96	28.11	20.07	17.90
Liquid Fuel	6.89	13.50	11.36	8.31	6.76
Total	56.20	93.79	90.27	64.35	54.31
Other Mines					
Heating & Cooling	1.56	2.35	1.95	1.60	1.25
Process Heat-Intermediate	28.65	45.02	40.66	30.48	25.31
Process Heat-High	24.27	39.23	36.49	26.39	22.49
Electricity Specific	24.39	35.30	32.08	25.05	20.47
Liquid Fuel	23.76	34.65	28.85	24.31	19.13
Total	102.63	156.55	140.03	107.83	88.65
Food Processing					
Heating & Cooling	0.35	0.36	0.26	0.31	0.25
Process Heat-Intermediate	55.43	54.68	42.51	46.65	38.05
Process Heat-High	29.53	28.55	21.71	23.47	19.28
Electricity Specific	13.19	12.87	8.68	10.73	8.95
Liquid Fuel	12.11	13.19	9.40	9.34	7.76
Total	110.61	109.65	82.56	90.50	74.29

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-6 (continued)
INDUSTRIAL ENERGY USE IN CANADA (PJ)

SUBSECTOR		Business As Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Pulp & Paper					
Heating & Cooling	1.40	2.57	2.13	1.76	1.29
Process Heat-Intermediate	401.56	535.00	313.81	367.86	227.80
Process Heat-High	82.23	123.24	112.36	85.30	71.32
Electricity Specific	55.43	65.83	44.16	48.85	28.54
Liquid Fuel	6.94	9.20	6.39	6.50	3.92
Total	547.56	735.84	478.85	510.27	332.87
Iron & Steel					
Process Heat-Intermediate	13.40	25.20	27.10	17.90	20.50
Process Heat-High	267.50	392.31	445.93	276.55	315.30
Electricity Specific	16.71	34.42	42.24	25.05	28.59
Liquid Fuel	1.03	1.87	2.06	1.34	1.55
Total	240.64	453.80	517.33	320.84	365.94
Smelting & Refining					
Heating & Cooling	0.09	0.24	0.18	0.15	0.10
Process Heat-Intermediate	13.50	32.60	24.09	16.69	13.83
Process Heat-High	54.41	99.38	90.42	66.80	53.96
Electricity Specific	105.95	185.64	188.18	133.16	113.72
Liquid Fuel	0.44	0.84	0.68	0.54	0.40
Total	178.39	318.70	303.55	217.34	182.01
Cement					
Heating & Cooling	0.12	0.12	0.08	0.10	0.07
Process Heat-High	54.68	63.63	45.12	46.13	34.21
Electricity Specific	3.30	4.04	2.85	2.88	2.34
Liquid Fuel	1.35	1.40	0.26	1.25	0.23
Total	59.45	69.19	48.31	50.36	36.85
Chemicals					
Heating & Cooling	28.10	36.13	23.33	25.40	15.96
Process Heat-Intermediate	110.31	141.87	85.07	92.52	62.23
Process Heat-High	55.83	72.76	42.29	47.05	30.64
Electricity Specific	45.28	54.77	33.65	34.12	24.20
Liquid Fuel	4.91	6.11	2.71	4.81	2.51
Total	244.43	311.64	187.05	203.90	135.54

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-6 (continued)
INDUSTRIAL ENERGY USE IN CANADA (PJ)

SUBSECTOR		Business As Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Other Manufacturing					
Heating & Cooling	28.51	40.82	29.30	26.68	21.41
Process Heat-Intermediate	148.08	215.42	173.07	149.47	127.18
Process Heat-High	138.76	210.92	171.47	141.20	125.19
Electricity Specific	70.71	91.65	67.12	62.84	51.74
Liquid Fuel	17.46	32.64	29.48	24.52	23.94
Total	403.52	591.45	470.44	404.71	349.46
Construction					
Heating & Cooling	11.60	12.69	9.05	9.24	7.35
Process Heat-Intermediate	0.36	0.36	0.23	0.28	0.19
Electricity Specific	2.47	1.56	0.49	1.44	0.41
Liquid Fuel	62.76	78.69	63.19	62.90	53.06
Total	77.19	93.30	72.96	73.86	61.01
Totals					
Heating & Cooling	92.71	115.63	84.72	82.48	63.41
Process Heat-Intermediate	783.16	1070.62	726.71	736.54	526.98
Process Heat-High	664.41	1060.43	995.84	733.94	689.87
Electricity Specific	373.81	527.20	458.32	374.72	306.61
Liquid Fuel	311.99	363.53	298.61	290.60	247.15
Total	2226.08	3137.41	2564.20	2218.28	1834.02

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-7

TRANSPORTATION ENERGY USE IN CANADA
(PJ)

SUBSECTOR		Business As Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
Air					
Liquid Fuel	136.59	261.56	286.50	165.03	190.57
Marine					
Liquid Fuel	99.55	132.55	135.61	94.86	90.46
Rail					
Electricity Specific	0.02	18.93	28.19	14.65	20.41
Liquid Fuel	88.14	81.71	70.40	53.40	45.55
Total	88.16	100.64	98.59	68.05	65.96
Truck Transport					
Liquid Fuel	331.69	456.57	458.58	322.98	323.51
Inter-Urban Buses					
Liquid Fuel	24.10	54.44	53.96	32.66	34.92
Urban Transit					
Electricity Specific	1.91	5.92	7.87	3.35	4.48
Liquid Fuel	16.92	36.77	35.93	22.34	21.93
Total	18.83	42.69	43.80	25.69	26.41
Automobiles					
Electricity Specific	--	15.60	34.25	25.90	35.90
Liquid Fuel	991.13	510.46	365.94	383.71	229.61
Total	991.13	526.06	400.19	409.61	265.51
Totals					
Electricity Specific	1.93	40.45	70.31	43.90	60.79
Liquid Fuel	1688.12	1536.06	1406.92	1075.02	936.55
Total	1690.05	1576.51	1477.23	1118.92	997.34

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-8

ENERGY END-USES IN CANADA IN 2000
BUSINESS AS USUAL SCENARIO
(PJ)

	Coal & Peat	Natural Gas	RPP's	Elec-tricity	Biomass Solids	Biomass Fluids*	Active Solar	Total
Residential								
Heating & Cooling	2.00	292.23	68.38	175.67	98.55	17.77	42.27	696.87
Electricity Specific	--	--	--	142.43	--	--	--	142.43
Total	2.00	292.23	68.38	318.10	98.55	17.77	42.27	839.30
Commercial								
Heating & Cooling	3.13	219.68	44.16	37.67	31.45	10.52	36.44	383.05
Electricity Specific	--	--	--	303.18	--	--	--	303.18
Total	3.13	219.68	44.16	340.85	31.45	10.52	36.44	686.23
Industrial								
Heating & Cooling	0.08	53.94	15.15	13.65	8.00	4.89	19.92	115.63
Process Heat-Intermediate	52.04	346.15	64.57	21.34	548.09	15.04	24.39	1070.62
Process Heat-High	292.89	443.62	78.01	67.76	152.15	21.00	4.00	1060.43
Electricity Specific	--	--	--	527.20	--	--	--	527.20
Liquid Fuel	3.00	2.76	224.96	--	--	132.01	--	363.53
Total	348.01	846.47	382.69	629.95	708.24	173.74	48.31	3137.41
Transportation								
Electricity Specific	--	--	--	40.45	--	--	--	40.45
Liquid Fuel	10.36	31.38	916.66	--	--	577.66	--	1536.06
Total	10.36	31.38	916.66	40.45	--	577.66	--	1576.51
Totals								
Heating & Cooling	5.21	565.85	127.69	226.99	138.00	33.18	98.63	1195.55
Process Heat-Intermediate	52.04	346.15	64.57	21.34	548.09	15.04	24.39	1070.62
Process Heat-High	292.89	443.62	78.01	67.76	152.15	21.00	4.00	1060.43
Electricity Specific	--	--	--	1013.26	--	--	--	1013.26
Liquid Fuel	13.36	34.14	1141.62	--	--	710.47	--	1899.59
Total	363.50	1389.76	1411.89	1329.35	838.24	779.69	127.02	6239.45

* The Biomass Fluids column also includes 216 PJ of methanol derived from natural gas.

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-9

ENERGY END-USES IN CANADA IN 2025
BUSINESS AS USUAL SCENARIO
(PJ)

	Coal & Peat	Natural Gas	RPP's	Electricity	Biomass Solids	Biomass Fluids	Active Solar	Total
Residential								
Heating & Cooling	3.00	128.15	13.97	128.16	128.86	43.37	85.42	530.93
Electricity Specific	--	--	--	142.42	--	--	--	142.42
Total	3.00	128.15	13.97	270.58	128.86	43.37	85.42	673.35
Commercial								
Heating & Cooling	1.40	105.56	0.56	38.34	34.50	17.61	74.83	272.80
Electricity Specific	--	--	--	301.68	--	--	--	301.68
Total	1.40	105.56	0.56	340.02	34.50	17.61	74.83	574.48
Industrial								
Heating & Cooling	2.05	5.33	3.34	11.34	17.86	8.54	36.26	84.72
Process Heat-Intermediate	29.58	114.03	7.79	22.05	444.19	10.04	99.03	726.71
Process Heat-High	349.99	163.88	24.95	36.59	302.00	107.43	11.00	995.84
Electricity Specific	--	--	--	458.32	--	--	--	458.32
Liquid Fuel	7.00	--	18.13	--	--	273.48	--	298.61
Total	388.62	283.24	54.21	528.30	764.05	399.49	146.29	2564.20
Transportation								
Electricity Specific	--	--	--	70.31	--	--	--	70.31
Liquid Fuel	29.65	--	102.89	--	--	1274.38	--	1406.92
Total	29.65	--	102.89	70.31	--	1274.38	--	1477.23
Totals								
Heating & Cooling	6.45	239.14	17.87	177.84	181.22	69.44	196.41	888.37
Process Heat-Intermediate	29.58	114.03	7.79	22.05	443.19	10.04	99.03	726.71
Process Heat-High	349.99	163.84	24.95	36.59	303.00	107.43	11.00	995.84
Electricity Specific	--	--	--	972.73	--	--	--	972.73
Liquid Fuel	36.65	--	120.98	--	--	1547.94	--	1705.53
Total	422.67	517.05	171.55	1209.21	927.41	1734.85	306.44	5289.18

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-10

ENERGY END-USES IN CANADA IN 2000
CONSUMER SATURATION SCENARIO
(PJ)

	Coal & Peat	Natural Gas	RPP's	Elec-tricity	Biomass Solids	Biomass Fluids	Active Solar	Total
Residential								
Heating & Cooling	2.00	306.29	38.24	174.21	106.70	17.72	45.40	690.56
Electricity Specific	--	--	--	141.93	--	--	--	141.93
Total	2.00	306.29	38.24	316.14	106.70	17.72	45.40	832.49
Commercial								
Heating & Cooling	0.53	198.49	3.07	25.95	29.22	7.82	36.80	301.88
Electricity Specific	--	--	--	221.83	--	--	--	221.83
Total	0.53	198.49	3.07	247.78	29.22	7.82	36.80	523.71
Industrial								
Heating & Cooling	0.06	37.47	10.76	9.01	5.93	3.96	15.29	82.48
Process Heat-Intermediate	28.37	246.36	32.65	15.41	380.90	9.95	22.90	736.54
Process Heat-High	204.39	247.12	42.26	39.45	183.64	14.08	3.00	733.94
Electricity Specific	--	--	--	374.72	--	--	--	374.72
Liquid Fuel	2.00	2.54	166.12	--	--	119.94	--	290.60
Total	234.82	533.49	251.79	438.59	570.47	147.93	41.19	2218.28
Transportation								
Electricity Specific	--	--	--	43.90	--	--	--	43.90
Liquid Fuel	8.88	35.35	677.83	--	--	352.96	--	1075.02
Total	8.88	35.35	677.83	43.90	--	352.96	--	1118.92
Totals								
Heating & Cooling	2.59	542.25	52.07	209.17	141.85	29.50	97.49	1074.92
Process Heat-Intermediate	28.37	246.36	32.65	15.41	380.90	9.95	22.90	736.54
Process Heat-High	204.39	247.12	42.26	39.45	183.64	14.08	3.00	733.94
Electricity Specific	--	--	--	782.38	--	--	--	782.38
Liquid Fuel	10.88	37.89	843.96	--	--	472.90	--	1365.62
Total	246.23	1073.62	970.93	1046.41	706.39	526.83	123.39	4693.40

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-11

ENERGY END-USES IN CANADA IN 2025
CONSUMER SATURATION SCENARIO
(PJ)

	Coal & Peat	Natural Gas	NGL's	Elec-tricity	Biomass Solids	Biomass Fluids	Active Solar	Total
Residential								
Heating & Cooling	3.00	97.53	6.43	120.10	141.25	67.56	97.12	532.99
Electricity Specific	--	--	--	142.28	--	--	--	142.28
Total	3.00	97.53	6.43	262.38	141.25	67.56	97.12	675.27
Commercial								
Heating & Cooling	0.30	70.66	0.30	24.03	24.85	15.74	60.07	195.95
Electricity Specific	--	--	--	225.40	--	--	--	225.40
Total	0.30	70.66	0.30	249.43	24.85	15.74	60.07	421.35
Industrial								
Heating & Cooling	2.05	0.11	1.68	7.42	13.57	7.69	30.89	63.41
Process Heat-Intermediate	27.33	40.77	6.50	12.61	333.41	24.80	81.56	526.98
Process Heat-High	248.66	34.00	14.74	46.19	257.28	79.00	10.00	689.87
Electricity Specific	--	--	--	306.61	--	--	--	306.61
Liquid Fuel	6.00	--	12.38	--	--	220.77	--	247.15
Total	284.04	74.88	35.30	372.83	604.26	340.26	122.45	1830.02
Transportation								
Electricity Specific	--	--	--	60.79	--	--	--	60.79
Liquid Fuel	21.22	--	39.65	--	--	875.68	--	936.55
Total	21.22	--	39.65	60.79	--	875.68	--	997.34
Totals								
Heating & Cooling	5.35	168.30	8.41	151.55	179.67	91.00	188.08	792.36
Process Heat-Intermediate	27.33	40.77	6.50	12.61	334.41	24.80	81.56	527.98
Process Heat-High	248.66	34.00	14.74	46.19	253.98	81.30	10.00	689.87
Electricity Specific	--	--	--	735.08	--	--	--	735.08
Liquid Fuel	27.22	--	52.03	--	--	1104.40	--	1183.69
Total	308.56	243.07	81.68	945.43	770.36	1299.24	279.64	3927.98

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-12

PRODUCTION OF PRIMARY SOURCES AND SECONDARY FORMS
IN CANADA IN 2000
BUSINESS AS USUAL SCENARIO
(PJ)

PRIMARY SOURCES					SECONDARY FORMS					
Source	**Production**	**Net Imports**	**Avail-ability**	**Energy Supply Sector**	**Production**	**Net Imports**	**Energy Supply Sector**	**Non-Energy Use**	**Energy Use**	**Form**
COAL & PEAT	904.57	235.77	125.00	2.73	122.75	--	--	--	122.75	COAL & PEAT
			304.03	25.15	278.80	--	--	145.30	133.50	COKE
			106.26	12.01	94.25	--	--	--	94.25	COKE OVEN GAS
			502.57	378.01	204.56	*	*	*	*	ELECTRICITY
			22.00	9.00	13.00	--	--	--	13.00	METHANOL
NATURAL GAS	2027.20	(67.00)	2204.14	101.36	1906.78	--	225.22	291.80	1389.76	NATURAL GAS
					216.00	--	--	--	216.00	METHANOL
			76.06	50.20	25.06	*	*	*	*	ELECTRICITY
CRUDE	2396.70	(39.21)	2356.85	--	2356.85	--	220.06	724.90	1411.89	RPP's
			0.60	0.42	0.22	*	*	*	*	ELECTRICITY
URANIUM	766.38	--	766.38	536.07	229.91	*	*	*	*	ELECTRICITY
HYDRO	1203.29	--	1203.29	--	1203.29	*	*	*	*	ELECTRICITY
ACTIVE SOLAR	130.12	--	127.02	--	127.02	--	--	--	127.02	ACTIVE SOLAR
			3.10	--	3.10	*	*	*	*	ELECTRICITY
WIND	7.16	--	7.16	--	7.16	*	*	*	*	ELECTRICITY
BIOMASS	2170.09	--	887.05	8.01	879.04	--	41.60	--	838.24	BIOMASS SOLIDS
			1129.22	433.68	695.54	--	108.55	--	586.99	METHANOL
			14.30	0.70	13.60	--	--	--	13.60	VEGETABLE OIL
			103.13	48.83	54.30	--	11.20	--	43.10	BIOGAS
			35.59	24.46	11.13	*	*	*	*	ELECTRICITY
					[1685.23]	(157.63)	198.25	--	1329.35	TOTAL ELECTRICITY
TOTAL	10005.51	109.56	10115.05	1671.03	8444.04	(157.63)	884.88	1162.08	6239.45	TOTAL

* All flows of secondary electricity are shown on the Total Electricity line.

SOURCE: FRIENDS OF THE EARTH SOFT ENERGY PATH STUDY 1983

TABLE CA-13

PRODUCTION OF PRIMARY SOURCES AND SECONDARY FORMS
IN CANADA IN 2025
BUSINESS AS USUAL SCENARIO
(PJ)

PRIMARY SOURCES					SECONDARY FORMS					
SOURCE	Production	Net Inflow	Avail-ability	Energy Supply Sector	Production	Net Inflow	Energy Supply Sector	Non-Energy Use	Energy Use	FORM
COAL & PEAT	791.41	209.52	139.43	2.73	136.70	--	--	--	136.70	COAL & PEAT
			348.10	28.80	319.30	--	--	177.08	142.22	COKE
			123.66	13.91	109.75	--	--	--	109.75	COKE OVEN GAS
			323.79	211.71	112.03	*	*	*	*	ELECTRICITY
			66.00	23.00	43.00	--	9.00	--	34.00	METHANOL
NATURAL GAS	1164.29	(31.00)	1132.84	5.37	1127.47	--	102.32	508.10	517.05	NATURAL GAS
			0.45	0.30	0.15	*	*	*	*	ELECTRICITY
CRUDE	1054.43	--	1054.24	--	1054.24	--	97.47	785.22	171.55	RPP's
			0.19	0.13	0.06	*	*	*	*	ELECTRICITY
URANIUM	--	--	--	--	--	*	*	*	*	ELECTRICITY
HYDRO	1376.03	*	1376.03	*	1376.03	*	*	*	*	ELECTRICITY
ACTIVE SOLAR	334.48	--	306.44	--	306.44	--	--	--	306.44	ACTIVE SOLAR
			28.04	--	28.04	*	*	*	*	ELECTRICITY
WIND	30.90	--	30.90	--	30.90	*	*	*	*	ELECTRICITY
BIOMASS	4296.64	--	983.72	10.81	972.91	--	45.50	--	927.41	BIOMASS SOLIDS
			2870.36	950.21	1920.15	--	391.67	--	1528.48	METHANOL
			93.30	4.60	88.70	--	--	--	88.70	VEGETABLE OIL
			236.87	101.20	135.67	--	18.00	--	117.67	BIOGAS
			104.39	71.00	33.39	*	*	*	*	ELECTRICITY
					[1580.60]	(178.52)	192.87	--	1209.21	TOTAL ELECTRICITY
TOTAL	9048.18	178.52	9226.70	1431.77	7794.93	(178.52)	856.83	1470.40	5209.10	TOTAL

* All flows of secondary electricity are shown on the Total Electricity line.

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-14

PRODUCTION OF PRIMARY SOURCES AND SECONDARY FORMS
IN CANADA IN 2000
CONSUMER SATURATION SCENARIO
(PJ)

	PRIMARY SOURCES				SECONDARY FORMS					
Source	**Production**	**Net Inflow**	**Avail-ability**	**Energy Supply Sector**	**Production**	**Net Inflow**	**Energy Supply Sector**	**Non-Energy Use**	**Energy Use**	**Form**
COAL & PEAT	681.70	121.12	78.14	3.88	74.26	--	--	--	74.26	COAL & PEAT
			217.00	18.14	198.86	--	--	103.38	95.48	COKE
			74.91	8.42	66.49	--	--	--	66.49	COKE OVEN GAS
			412.77	267.78	144.99	●	●	●	●	ELECTRICITY
			20.00	7.00	13.00	--	3.00	--	10.00	METHANOL
NATURAL GAS	1531.12	(87.00)	1418.91	7.19	1411.72	--	135.00	203.10	1073.62	NATURAL GAS
			25.21	16.64	8.57	●	●	●	●	ELECTRICITY
CRUDE	1655.07	--	1654.69	--	1654.69	--	165.21	518.55	970.93	RPP's
			0.38	0.25	0.13	●	●	●	●	ELECTRICITY
URANIUM	603.08	--	603.08	422.17	180.91	●	●	●	●	ELECTRICITY
HYDRO	1162.19	--	1162.19	--	1162.19	●	●	●	●	ELECTRICITY
ACTIVE SOLAR	126.64	--	123.39	--	123.39	--	--	--	123.39	ACTIVE SOLAR
			3.25	--	3.25	●	●	●	●	ELECTRICITY
WIND	6.78	--	6.78	--	6.78	●	●	●	●	ELECTRICITY
BIOMASS	1960.56	--	752.12	8.03	744.09	--	37.70	--	706.39	BIOMASS SOLIDS
			1059.59	413.72	645.87	--	174.14	--	471.73	METHANOL
			12.20	0.60	11.60	--	--	--	11.60	VEGETABLE OIL
			103.03	48.73	54.30	--	11.20	--	43.10	BIOGAS
			33.62	23.67	9.95	●	●	●	●	ELECTRICITY
					[1516.77]	(300.56)	169.00	--	1046.41	TOTAL ELECTRICITY
TOTAL	7727.14	34.12	7761.26	1246.22	6515.04	(300.56)	696.05	825.03	4693.40	TOTAL

● All flows of secondary electricity are shown on the Total Electricity line.

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

TABLE CA-15

PRODUCTION OF PRIMARY SOURCES AND SECONDARY FORMS
IN CANADA IN 2025
CONSUMER SATURATION SCENARIO
(PJ)

PRIMARY SOURCES					SECONDARY FORMS					
SOURCE	Production	Net Inflow	Avail-ability	Energy Supply Sector	Production	Net Inflow	Energy Supply Sector	Non-Energy Use	Energy Use	FORM
COAL & PEAT	577.07	154.18	96.54	3.88	92.66	--	--	--	92.66	COAL & PEAT
			263.11	21.77	241.34	--	--	133.98	107.36	COKE
			93.06	10.52	82.54	--	--	--	82.54	COKE OVEN GAS
			228.54	150.19	78.35	*	*	*	*	ELECTRICITY
			50.00	17.00	33.00	--	7.00	--	26.00	METHANOL
NATURAL GAS	705.80	(24.40)	681.25	3.14	678.11	--	65.64	369.40	243.07	NATURAL GAS
			0.15	0.10	0.05	*	*	*	*	ELECTRICITY
CRUDE	732.65	--	732.65	--	732.65	--	68.83	582.14	81.68	RPP's
			--	--	--	*	*	*	*	ELECTRICITY
URANIUM	--	--	--	--	--	*	*	*	*	ELECTRICITY
HYDRO	1335.58	--	1335.58	--	1335.58	*	*	*	*	ELECTRICITY
ACTIVE SOLAR	295.29	--	279.64	--	279.64	--	--	--	279.64	ACTIVE SOLAR
			15.65	--	15.65	*	*	*	*	ELECTRICITY
WIND	28.02	--	28.02	--	28.02	*	*	*	*	ELECTRICITY
BIOMASS	3373.37	--	823.08	8.52	814.56	--	44.20	--	770.36	BIOMASS SOLIDS
			2132.27	719.27	1413.00	--	309.61	--	1103.39	METHANOL
			78.20	3.80	74.40	--	--	--	74.40	VEGETABLE OIL
			242.78	103.33	139.45	--	18.00	--	121.45	BIOGAS
			97.04	68.31	28.73	*	*	*	*	ELECTRICITY
					[1486.38]	(363.01)	177.94	--	945.43	TOTAL ELECTRICITY
TOTAL	7047.78	129.78	7177.56	1109.83	6067.73	(363.01)	691.22	1085.52	3927.98	TOTAL

* All flows of secondary electricity are shown on the Total Electricity line.

**SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983**

CHAPTER 4: POLICY IMPLICATIONS, IMPLEMENTATION AND IMPACTS

It has been said that we cannot predict the future, but that we can design it. This study accepts that dictum. It does not pretend to predict energy supply or demand in Canada, but it does offer a pair of alternative designs for them. Chapter 3 has shown that these designs are feasible. Therefore, the questions become: How could the designs be implemented? and, What would be the impacts of such implementation? Those questions will be the focus of this chapter.

While it is necessary for analysts to step beyond research results and deal with policy, it is dangerous ground on which to walk. One can be reasonably confident of the quantitative results in Chapter 3, and also of of some general policy implications that can be drawn from those results (described in in Section 4.1 below). One has to be less confident about specific suggestions concerning implementation programs to get Canada onto a soft path (Section 4.2) and about the impacts of such policies and programs (Section 4.3). However, it would be inappropriate to refrain from making some comments on these areas because of uncertainty or lack of complete analysis. All energy policy suffers from the same problems, and most policy choices have to be made with only a limited knowledge of social costs and benefits.

4.1 POLICY IMPLICATIONS

Policy implications that can be drawn from the results of this study are identified in this section of the chapter. A number of caveats should be borne in mind. First, the list is not comprehensive; a detailed review of our results would no doubt identify many other policy implications. Second, emphasis has been placed on implications that follow directly from the results of this study rather than on those related to soft energy paths generally. Third, most soft energy policies need to be developed, or at least adapted, at local and regional levels. Central governments and agencies can coordinate activities and provide the right environment, but they are unlikely to be able to enlist people or deliver programs in the most appropriate ways to all the different parts of Canada, Finally, there is no neat list of programs and policy measures that will suffice to bring about the soft energy path results described in Chapter 3. Rather, what is required is a commitment to long-range goals while remaining flexible in dealing with near-term developments and local conditions.

Having made those caveats, there are several broad areas where central governments have to establish a framework: appropriate pricing, balanced incentives, availability of information, and economic growth. Following a discussion of these general implications, the rest of this section will be organized by energy quality categories. Some policy topics do not divide conveniently this way, so general comments about residential and commercial energy are discussed under Heating and Cooling, those about industry under Process Heat and those about transportation under Liquid Fuel.

General Policy Implications

(1) The most critical yet least unexpected policy implication of this study is that energy prices play a direct and strong role in determining the energy future a society gets. By assuming in this study that those prices are set on the basis of marginal costs, it has been possible to show that, from the standpoint of economic efficiency alone, a very different set of supply and demand patterns would gradually develop to replace those that exist today. *However, in contrast to the common expectation, the main results of higher prices would not be a shift of economic activity to new energy supply but a shift to energy productivity (i.e. conservation).* Unfortunately, Canadian energy prices are far from satisfying our assumption. Oil, natural gas and especially electricity are priced below their respective marginal cost. As a result, consumers are simultaneously encouraged to demand more energy than is appropriate and producers -- whether of new or of conventional sources -- are discouraged from producing more to meet those demands.

The emphasis on pricing is not intended to pretend that prices are truly objective measures nor to ignore the imperfections that separate even competitively determined prices from true marginal (or, more loosely, replacement) costs. However, no other measure offers so useful and so widely accepted a guideline for adjusting inputs and outputs and for selecting among alternative investments. Marginal cost pricing may create other problems, but in most cases it is easier to resolve such problems directly than to accept the subsidization of large areas of the economy, which is what today's pricing patterns entail. In sum, energy prices based on marginal costs appear to be a necessary though not a sufficient condition for a soft energy future.

(2) There is probably no other sector of the economy with so many barriers and incentives, some conflicting and many overlapping, as the energy sector. Little effort has been made to sort these out in this study, but it is evident that those barriers and incentives are such that; (a) demand reducing opportunities are disadvantaged relative to supply expanding ones; and (b) renewable and decentralized supply opportunities are disadvantaged relative to nonrenewable and centralized ones. (For an extensive review of barriers and incentives relative to soft paths in Canada, see Elder, 1982.) Because of strong evidence

for the cost-effectiveness of many energy conserving and renewable energy technologies, it is an obvious policy implication that the barriers and incentives should be adjusted so that soft options receive a better deal. Whether this is done by raising the incentives or reducing the barriers for soft sources, or by reducing the incentives or raising the barriers for hard ones, or by some combination of the two is not relevant to the immediate purpose of this study. (However, in common with many other people, most of the participants in this study would prefer, where possible, to see equity between soft and hard options effected with less rather than with more government.) Reference is made in sections below to barriers and incentives that turned out to be particularly critical for the technologies employed in this study.

(3) The fact that many cost-effective soft energy options are not adopted suggests that the role for government in the provision of information may be even greater than the substantial role it has taken to date. In particular, this study indicates that householders and firms may have general information on energy but lack information that would be specifically useful when making investment decisions. A start has been made with the efficiency lists for autos and Energuide labels on appliances, but much more is needed. For example, schemes have been developed, but none implemented to our knowledge in Canada, to label houses and buildings for their energy efficiency. Audits of energy use in homes, buildings and industry should be provided at cost (by firms different from that actually engaged in retrofit work), and should include specific suggestions for expenditure. Testing, monitoring and follow-up should also be included. Examples of approaches to such "full service" audits include "house doctors" and energy service corporations. The provision of information can be extended to demonstration projects. It is evident that many builders, for example, are not yet aware of how to design and build truly energy-efficient structures. Information availability also involves the training of builders, inspectors, engineers and designers. Many more people must come to understand the concepts and techniques for delivering energy services in an efficient way. Dollars spent in training will likely be highly productive in saving dollars that would otherwise be spent on energy.

(4) Finally, it is evident from the differences between the two scenarios presented in this study that, even within a soft path approach, the rate of economic growth has a significant influence on energy use. There is nothing surprising in this result. The very nature of energy implies that the greater the activity in any economy, the greater will be its needs for energy services. (There is also some reverse causation. Efforts to increase either energy supply or energy efficiency can stimulate economic growth, but this effect is much weaker than that from the economy to energy.) However the great disparity between the amount of energy required to supply a given energy service, such

as space heating, and that typically supplied, is such that growing levels of demand for those services can be met in many cases with actual reductions in the amount of energy supplied. Moreover, higher rates of economic growth may make it possible to replace older, less efficient plant and equipment more rapidly. This latter effect is illustrated in our results by some greater conservation effects in the Business as Usual than in the Consumer Saturation scenario. In our analysis, the net effect of these two influences (growing demands for services, reductions in the energy needed to supply these services) is that the linkage between economic growth and energy growth is far below the one-to-one relationship that was once supposed, although it is nevertheless positive.

Governments have a pre-eminent role in setting economic conditions, and in performing that role it is essential that they recognize the positive linkage between income and energy. Such recognition does not imply that the former should be curbed to reduce the latter, but it does mean that the requirements of a larger economy, no matter how efficient, for more costly energy, together with the environmental and social costs of getting that energy, should be taken into account in making economic policy decisions.

Heating and Cooling

In principle low-temperature energy for Heating and Cooling services should be the easiest to provide, and in practice it is. By far the cheapest source for low-temperature heat is that already existing because of other activities. It can be either trapped in place, which is generally termed energy conservation, or moved from where it is available to where it can be used, which is generally termed waste heat utilization (though there is no essential difference between the two). The sources of low-temperature heat to provide Heating and Cooling are so large and so ubiquitous that it is only a small exaggeration to say that ultimately, even in Canada, requirements for external sources of low-temperature heat should drop to zero. In the Business as Usual scenario energy requirements for Heating and Cooling (which includes low-temperature Process Heat in industry) fall from nearly 2 to less than 1 exajoule over 47 years, and they are still falling at the end of the study period.

Several policy implications derive from this general result. Above all, every effort must be made to publicize the remarkable cost-effectiveness of super-energy-efficient buildings, including both new construction and retrofits. This effort should include everything from information and audit programs through demonstrations to various kinds of incentives. Granted that all of these approaches are already being tried, the number of poor quality structures still being built, and the difficulties turning up in some retrofits, indicates that additional efforts are called for. Perhaps programs aimed at the Residential and Commercial sectors should be less uniform across the country and allow greater variation by province. The need for "labels" on buildings similar to those for autos has already been noted. Moreover, there are a number of key institutional problems that were recognized early but that remain unsolved. For example, the incentives for builders and developers to minimize inital cost prior to selling means that buildings are not optimized for minimum life-cycle costs, including energy costs. (The same people also commonly buy and install energy-inefficient appliances for apartment and housing developments: see the Electricity Specific section below.) It is no accident that the best commercial buildings in Canada have been built by a firm that retains ownership throughout the design, construction and operation stages. Another problem stems from the large number of tenants in Canada who pay their own utilities, which means little incentive for either tenant or landlord to invest in energy conservation. Such problems may have to be solved by design standards and retrofit standards that serve to replace the misdirected incentives of the market. The lifetime of buildings is long so that failure to act in these areas imposes a very high cost on the economy.

Implicit in the discussion of Heating and Cooling energy is the need for innovative financing schemes within the Residential and Commercial sectors. Institutions, just as individuals, tend to financial myopia. It has been suggested that provincial utilities and natural gas firms, for example, offer loans at just above their borrowing rates to promote investment in energy-efficient buildings and appliances. Even though such loans would reduce their load growth, the return could well be greater than that from continued investment in new capacity.

A corollary to the conclusion that most heating and cooling energy can be provided by conservation and waste heat utilization is that, in super-energy-efficient buildings, capital costs quickly overshadow fuel costs on a life-cycle basis. Hence, there is every reason to expect a market to develop for lower cost heating/cooling systems, and in particular for relatively small systems that provide energy in a storable form (e.g. wood, bottled gas). Physically the objective is to identify energy forms that can provide back-up when needed, and economically it is to identify systems that are low in capital cost, even if they may be high in operating cost, to offset the reverse economic characteristics of improved design. (High operating cost is not so important for systems that are used only intermittently.) However, a variety of alternative, relatively capital-intensive systems -- notably heat pumps and active solar systems -- have also been put forward for consideration as sources of back-up energy. All deserve investigation to test both for life-cycle cost minimization to the consumer and for system efficiency including peaking problems. Until the true zero-energy structure is widely available, policies and programs for system integration have to be analyzed.

Although both at present and in our projections, the use of biomass as a source of Heating and Cooling energy is far below its use as a source of Process Heat in industry, it is worth looking at some implications for the Residential and Commercial sectors. In many parts of the country wood fuel in one of its forms -- logs, chips, pellets -- or peat is already the cheapest available fuel per delivered joule, even after allowing for lower efficiency of combustion compared with conventional forms of energy. Homeowners obviously recognize this situation: under the Federal government's Off-Oil incentive program, more people are converting to wood heating than to any other energy form. However, better standards, including safety and pollution standards, are needed for the combustion devices, as are labels about combustion efficiency with different kinds of biomass.

At the other end of the system, a lot of training and education is needed about woodlot management and cutting practices, along with the development of marketing channels and standards. In contrast to almost every other form of energy, the wood fuel industry is largely uncoordinated and unorganized. Land ownership, harvesting, transportation, equipment supply and retailing are each commonly under separate ownership. There is clearly a need for action here, and governments seem to be the most logical bodies to serve in this role (though we cannot be unmindful of the difficulties governments typically have in dealing with activities that cut across the lines of resources, manufacturing and consumer affairs). Given the diversity in land tenure and growing conditions across Canada, variations in approach will be wide, but organization of this industry to provide for a high yet sustainable level of wood fuel production is essential. Where new products need to be developed, as with wood pellets, demonstration projects or interim subsidies may be appropriate. And environmental standards for land use need to be established and enforced.

Finally, appropriate pricing cannot be neglected. The immediate policy problem is less the level of prices than that many people do not pay directly for energy they use and that some prices are structured so that unit energy costs decline as more is used. Except in the two territories, provincial policies are mainly to blame, and they should be adjusted to eliminate bulk metering and declining block rates and to reduce peak use of natural gas and electricity.

Process Heat

Medium- and High-Temperature Process Heat, both used exclusively by the Industrial sector, can be treated together. In the Business as Usual scenario they grow by nearly 50% during the 1978 to 2000 period before falling off thereafter so that growth over the whole period to 2025 is about 25%. In the Consumer Saturation scenario they hold steady between 1978 and 2000 but over the whole period fall by about 15%. For both scenarios, use shifts toward the higher temperature end of the spectrum.

Taking these figures at face value for the moment, what implications can be drawn? First and most important, they represent a challenge that cannot easily be met by soft energy. High temperatures are most easily produced by concentrated sources of energy, which generally means use of fossil fuels or, in special cases, electricity. Hence, it is even more important than elsewhere to ensure that this energy is used efficiently. From this point of view, it is of concern that the smelting and refining industry, one of the major users of high-temperature heat, is among the lowest of all the industrial subsectors in its projections of efficiency gains (Wolf, 1978). In all cases cascading and cogeneration are to be strongly encouraged so that high-temperature energy is used as intensively as possible before being rejected. It is also important that those industries that can use near-by sources of heat that may otherwise go unused (or create pollution), as with cement plants (which can burn municipal wastes), do so. Government policies and programs should be designed to encourage new energy-conserving investment in the appropriate industries, though it is not clear how much direct assistance would be needed if energy prices were determined by marginal costs. Presumably some firms and perhaps whole industries would need help to modernize, but, if the results are as cost-effective as they should be relative to the real costs of energy, assistance might be offered in the form of loans rather than grants.

Second, not only should firms using higher temperature heat be encouraged to capture waste heat in their own operations, but they should also be encouraged to make excess waste heat available for sale to other firms or to nearby communities. The potential in Canada for use of industrial waste heat in local district heating and water preheating is very large, but a variety of institutional adjustments need to be made to remove legal and financial disincentives in order for the potential to be realized (Ferguson _et_ _al_, 1979; Lalonde _et_ _al_, 1981). This point has special relevance for many remote communities, which could be well served with the waste heat from mining or forestry operations.

Third, and perhaps more important, every attempt should be made to encourage the increase of self-supply within industry through use of waste products. The major case in point is the pulp and paper industry, but significant opportunities exist with all forest industries, the food and beverage industry, the chemical industry and others. Opportunities for pollution abatement through the use of wastes can be considered simultaneously. Utility policies need to be adjusted as well as to encourage rather than discourage cogeneration (see Electricity Specific below) and government pricing policies to promote the sale of natural gas should not be designed to undercut the use of waste products as fuel.

Fourth, innovative policies will be needed if biomass fuels (mostly biomass solids) are to become a major source of industrial Process Heat. In 2025 in the Business as Usual scenario, some 860 PJ of biomass energy are used for Process Heat (680 PJ in Consumer Saturation) compared with around 170 PJ for Heating and Cooling (roughly the same in Consumer Saturation). Biomass comes to provide around two-thirds of the requirements for Intermediate-Temperature Process Heat in industry and two-fifths to one half those for High-Temperature Heat. Assistance, monitoring and no doubt regulation will be necessary to ensure that the transition from today's much lower levels of biomass use is safe and efficient, particularly as the situation shifts from one of largely self-supply within an establishment to large-scale harvesting and sale of biomass as an energy commodity. Government will probably have to sponsor the research and development required to develop efficient wood-fired boilers of various sizes, and it may also have to offer loans to permit firms to convert to such boilers as they come onto the market. Certainly, government will have to set emission standards, insist on appropriate land-use plans and ensure that reforestation takes place. The same points will occur and with even greater force below where biomass sources of Liquid Fuel are discussed.

Finally, it is important to ask whether there are ways to reduce the industrial requirements for the products that require higher temperature energy. It is relevant to recall that, by the workings of the LTSM, production levels for certain industries, notably steel, that require large amounts of higher temperature energy are probably overstated. Ignoring this, the important point is that opportunities to reduce the need for such commodities are not hard to find. Re-use of glass products, recycling of metals and farming methods that reduce the need for chemicals and fertilizers rank high. In addition, product standards should be established to ensure that consumer goods are designed so that they can be easily re-used or recycled, as with uniform shapes for bottles and careful listing of the alloy content of metals. Finally, but more difficult to effect with policy, is the need to promote better designed and more durable consumer products, most of which require somewhat greater inputs at the start but fewer over the effective life of the product.

Whatever success conservation may have, the requirements for industrial Process Heat in Canada will remain substantial, well over an exajoule. Biomass and waste products are likely to offer a growing opportunity, as will active solar systems over the longer term. (However, in contrast to biomass, lower temperature uses of active solar energy continue to predominate even though, by the end of the study period, the Industrial sector is taking nearly half of the output of active solar systems.) Biomass, waste and solar sources all deserve continuing support in experimental and demonstration projects. For the immediate future, however, the bulk of Process Heat requirements will be supplied by conventional fossil fuels, which means that government and industry should continue existing efforts to find ways to burn the fuels more efficiently and with minimum environmental damage.

Electricity Specific

The principal policy result of this study so far as electricity is concerned is that relatively little new capacity needs to be constructed in Canada for at least the next 50 years. Although there is a 33% increase in electricity use between 1978 and 2000 in the Business as Usual scenario (only 5% in Consumer Saturation), there was enough capacity already available (or under construction) in 1978 to provide for most of that increase. Moreover, between 2000 and 2025 the need for electricity would decrease in the Business as Usual scenario (drop below 1978 levels in Consumer Saturation), which suggests that it would be unwise to invest in construction projects whose output might not be needed for more than a few years. Indeed, in recognition of Canadian conditions, this study has allowed for the use of some electricity for Heating and Cooling where it is subject to substitution by other fuels, so, if anything, its cost-effective rate of use has been overstated. In addition, a small role for electricity in supplying High-Temperature Process Heat was incorporated for industries that require precision control or point-of-use cleanliness.

In order to achieve the efficiency gains in Electricity Specific uses projected in this study, governments will have to turn their attention from electricity generation to the end-uses of electricity and particularly to end-use devices such as motors and appliances. There is a role here for both competition and regulation. As for the former, it is evident that Japanese firms are approaching energy efficiency in appliances with the same force they have applied to automobiles. The average energy use of new refrigerators manufactured in Japan decreased from 105 to 39 kW.h per month from 1971 to 1980 while the average useful capacity increased by almost 40%; the average efficiency for 18-inch television sets almost doubled over the same period (The Energy Conservation Center, 1982). It would be a serious mistake for North American firms to ignore such developments, and the U.S. and Canadian governments can ensure that they do not by allowing Japanese products to compete fairly on North American markets. However, many appliances are purchased by owners of rented units or in bulk by developers logically more concerned with first cost than life-cycle cost. Hence, there may well be a role for federally-mandated appliance efficiency standards similar to those for automobiles.

An additional implication of the results presented here is the need to reject electrical resistance heating as a primary heating source, though not necessarily as a possible back-up source in super-energy-efficient buildings. The cost-effectiveness of electric heating (a non-Electricity-Specific use) is very sensitive to the level of efficiency achieved; electricity's share of Heating and Cooling energy increases as conservation measures are pushed to their cost-effective limit. However, systems that incorporate electrical back-up should ensure that peaking problems do not erode the benefits. Needless to say, both device and system efficiency would be enormously promoted by pricing electricity, which in most provinces is the most under-priced of all common energy forms, at its long-run marginal cost.

A general balance between supply and demand for electricity in Canada does not imply an absence of problems in specific provinces. Moreover, by explicitly excluding new nuclear plants from consideration and by trying to avoid coal-fired and large-scale hydro plants where possible, it was necessary to identify replacement capacity for 2025 (most of today's nuclear and coal plants are still operating in 2000). However, enough capacity could be found with only a modest expansion of today's hydraulic systems. In two of the most hydro-dependant provinces, British Columbia and Quebec, needed expansion in large dams beyond projects in place or under construction in 1978 is nil, even though both provinces are called upon to fill electricity deficits in other provinces (British Columbia in Alberta and Quebec in Ontario). A relatively small in-feed from Labrador to Newfoundland is also included, as is a tidal plant in Nova Scotia to supply maritime requirements. Hence, a further policy implication is that interprovincial electrical links appear to be sensible; while they will be expensive and cause some environmental damage, their costs should be lower and the damage less than other alternatives for supplying electrical requirements in a soft future. For example, instead of importing electricity from Quebec, Ontario could dam north-flowing rivers, something that would be strongly opposed by environmentalists and by native people.

Another policy implication is the need to promote investment in cogeneration wherever that can be shown to be cost-effective. This may be a difficult policy choice for provincial utilities already faced with over-capacity. Realizing the opportunity will require clear-cut and fair rules about both prices offered for surplus power and costs charged for providing back-up. However, the cogeneration potential appears to be too high, too widespread and too advantageous to neglect.

Alternative sources of electricity deserve policy support, including the development of appropriate environmental standards. Two that are likely to prove cost-effective in the near term, at least in the Atlantic provinces, are peat and wood (in plants of 20 to 120 MW capacity). Two that are likely to prove cost-effective only in the longer term, except in off-grid situations, are wind and solar photovoltaics. It is worth investigating whether such sources could lower system costs because of diversification, a better distribution of generating capacity relative to load or (in the case of wind) winter peaking capacity.

Liquid Fuel

By the end of the study period Liquid Fuel is mainly supplied in the form of methanol which in turn is based on biomass sources. To a very considerable extent, this is a transportation problem. Of the total use of liquids, about half went to the Transportation sector in 1978; by 2000 the share is 70% and by 2025 nearly 80% in the Business as Usual scenario. Moreover, the situation for neither has stabilized. Use of energy in the Transportation sector declines throughout the study period to 2025, but not by very much -- it still accounts for almost 1-1/2 exajoules in the Business As Usual scenario (1 exajoule in Consumer Saturation) -- and there is some suggestion that it could climb again after 2025. Total use of Liquid Fuel also declines over the study period, but again not by very much (from 2.0 to 1.7 exajoules in the Business as Usual scenario and to 1.2 exajoules in Consumer Saturation). Although the sources of Liquid Fuel are more diversified than in 1978, the use of biomass fluids is still rising in 2025 (when it accounts for about 0.9 to 1.3 exajoules). These trends are cause for concern and they indicate that in this study, as in almost every other soft energy study, the Transportation/Liquid Fuel nexus is the most difficult to resolve from both the demand and the supply points of view.

What policy implications can be derived from these results? First, efforts to stimulate the production and use of energy-efficient transportation vehicles must be strengthened. Canada cannot rest with the 1985 standard for automobiles (fleet average of 8.8 L/100 km) but must both continue the progress with automobiles and extend the approach to other modes of transportation, notably buses and trucks. Without continued progress in vehicle efficiency, the Transportation/Liquid Fuel problem will be serious indeed. Second, new efforts must be made to look at the transportation system, something that was not possible within the constraints of this study, and such efforts must make life-cycle energy costs at full marginal cost a prime consideration. (Individuals and firms may be forgiven if they make their energy decisions on the basis of subsidized prices, but there can be no excuse for governments, which do most of the transportation planning and pay most of the energy subsidies.) Such a review should include both passenger and freight movements and both urban and rural areas. And it must incorporate some long-term considerations, such as industrial location and urban design, as well as short-term ones such as pricing for transportation services, intermodal links and the numerous barriers to efficiency in moving people and goods.

Turning to the supply side, the main new form of Liquid Fuel in this study is methanol. The great bulk of that methanol is derived either from mill and forest residues or from managed forests and plantations. The exceptions include coal that is powdered and fed as a slurry in ocean-going steam vessels, low-Btu biogas generated from animal wastes and used locally, and vegetable oils used as a substitute for diesel oil. All are important opportunities, particularly the last, but, apart from support for research and demonstration projects and ensuring that inappropriate barriers do not block promising developments, it is not clear that any special policy consideration is needed at this time. Transitional transportation fuels include electricity, propane and compressed natural gas, and much the same comments apply to them.

At a more general level, the assumption that alternatives to petroleum will eventually be needed does not seem open to question (though the urgency of that need certainly is), but major policy choices lie in the selection of one or several of the opportunities open to Canada. This study has focused on the selection of methanol for the long term, but other opportunities including ethanol, hydrogen and electricity do exist and deserve further investigation. This study has also accepted that several fuels could co-exist, which has its own policy implications, but that there must be at least one automotive fuel available everywhere in Canada. Certainly before a long-term commitment to biomass-based methanol is made, one would have to assess the alternatives of relying for a longer term on an oil-based transportation system or of switching to a natural gas-based one (used directly in compressed form or after conversion to methanol or to gasoline itself).

The methanol opportunity in Canada seems good enough to justify an experiment with a biomass-based supply facility, including a full-scale demonstration project, probably using natural gas as the fuel and biomass as the raw material, and at the same time to create a market for the methanol in vehicles designed for its use. The idea is to break the chicken-and-egg problem: viz., engines to use methanol do not exist because the fuel system does not exist, and the fuel system does not exist because engines do not exist. Clearly, there is a role here for government, as will be discussed further in the section on Implementation below. However, there is one further aspect of methanol production that deserves emphasis at this point.

One of the barriers to increasing supply from conventional Liquid Fuel sources (such as oil sands plants or Arctic oil) is the huge capital cost necessary to bring them on stream. This "lumpiness" of necessary investments is not associated with the methanol-from-biomass option as the latter can be brought on stream economically at appropriate scales when needed. As shown in Table 4.1, to produce the amount of biomass-based methanol that is projected as needed in the Business as Usual scenario in 2000, about 115 plants producing 1000 tonnes per day of methanol would be needed (107 plants in Consumer Saturation). By 2025 the requirements for biomass-based methanol are much higher: 315 plants in the Business as Usual scenario (230 in Consumer Saturation). At about $181 million per plant, using the wood gasification process, cumulative investment in the Business as Usual scenario would grow from $21 billion in 2000 to $57 billion in 2025; in Consumer Saturation it would grow from $19 to $42 billion. As a rough comparison, the same table shows the number of tar sands plants required to obtain the same amount of energy. If each tar sands plant costs $12 billion, the capital cost of the methanol option would be substantially smaller, although these figures exclude feedstock costs for the methanol plants. Moreover, that investment would be widely distributed across the country (100 to 300 plants) instead of being concentrated in 2 to 7 tar sands plants.

4.2 IMPLEMENTATION

The previous section of this chapter derived policy implications from the results of this study. It remains to indicate something about the possibilities for actually getting from the base year 1978 to the projection years 2000 and 2025. This section will show that the changes necessary during intervening years are within the capabilities of the Canadian economy to accomplish and Canadian society to accept. The review will proceed by sector on the demand side and by energy form on the supply side. To emphasize those aspects most likely to cause problems, figures cited in this section of the chapter will refer to the Business as Usual scenario unless otherwise indicated. From most points of view, implementation would be less difficult under the Consumer Saturation scenario. In this context, it is worth noting that the 2% annual economic growth rate underlying the Consumer Saturation scenario is more representative of recent Canadian experience than the 3% rate (4.3% to 2000) underlying Business as Usual.

This study represents an energy version of what economists call comparative statics. It provides results for specific years but does not deal with the pattern of activity between those years. For the purposes of this section, it will be sufficient to indicate that the projected soft path results could, on the average, be achieved by implementation policies yielding equal changes from one year to the next. The comparative statics nature of the analysis is indicated by the bar charts (Fig-

TABLE 4.1

LIQUID FUEL PRODUCTION: BIOMASS-BASED METHANOL VS TAR SANDS OIL

	Business As Usual		Consumer Saturation	
	2000	2025	2000	2025
Projected Output (PJ)	700	1920	650	1410
Number of 1000 tpd methanol plants required*	115	315	107	231
Cumulative Investment for methanol plants ($ billions)	21	57	19	42
Number of 135 000 bpd tar sands plants to get same output**	2.4	6.5	2.2	4.8
Cumulative Investment for tar sands alternative ($ billions)	29	78	26	58

*Each plant produces 6.1 PJ/a.

**Each tar sands plant produces 300 PJ/a at 100% capacity.

ures 3.5 and 3.6 for end-use sectors; Figures 3.9 and 3.10 for energy forms; and Figures 3.17 and 3.18 for energy qualities), all of which show energy use for three specific years -- 1978, 2000 and 2025. By interpolation they also indicate the situation in 1990, but no explicit supply or demand analysis was performed for that year. Hence, only rough comparisons can be made with other reports that focus on 1990.

Demand

The impact of conservation on the Residential sector is separable into policies for new housing and for existing housing (retrofits). There are three time periods of interest: up to and including 1978, 1979 through 2000, and 2001 through 2025. (Of course, all housing in the base year 1978 is treated as existing, and any built new in the period 1979 through 2000 is treated as existing in the next period.) The housing mix exclusive of mobile homes is shown in Table 4.2.

TABLE 4.2
NEW AND RETROFIT HOUSING STOCK IN 2000 AND 2025
(thousand units)

HOUSING TYPE*	STOCK IN 1978	STOCK IN 2000			
		Pre-1979 Structures		Built after 1978	Total
		Unretrofit	Retrofit		
Single Family Detached	4061	1391	2680	2354	6415
Attached	897	246	562	710	1518
Apartment	2378	1180	1720	1231	4131
Total	7326	2807	4962	4295	12 064

HOUSING TYPE*	STOCK IN 2025			
	Pre-2001 Structures		Built after 2000	Total
	Unretrofit	Retrofit		
Single Family Detached	327	4965	1571	6863
Attached	90	1274	943	2307
Apartment	219	2681	1577	4477
Total	636	8920	4091	13 647

* Exclusive of mobile homes.

SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983

The table shows that the housing stock doubled in size and changed slightly in composition toward more multiple family units over the 47-year projection. (The two scenarios are identical in the size and composition of the Residential sector and almost identical in residential energy use.)

To start with existing units, Table 4.2 shows that almost two-thirds of the pre-1979 dwelling units still remaining in 2000 had been subject to major retrofit measures by that year and over 90% of the pre-2001 stock had been retrofitted by 2025. (Some units are retrofitted twice, once in each period.) Unit savings were generally between 50 and 70% of the original energy use. Before the year 2000 a greater share of single family detached dwellings are projected to be retrofitted, but after 2000 all dwelling types show comparable shares. If accomplished evenly, about 225 000 units would have to be retrofitted each year between 1978 and 2000, and 350 000 every year between 2001 and 2025.

The extent of retrofitting varied widely by province. In some provinces, 100% of existing housing still standing at the end of each period (that is, net of demolitions) had been subject to retrofit measures; in others the rate was as low as 25% in 2000 and 50% in 2025. However, in all cases, the rates are within the capability of the residential construction industry. Indeed, it can be argued that, with lower population growth, the building industry will have to turn to retrofit to maintain even its existing level of activity. Casual observation indicates the large number of new, generally small businesses that have been started to provide retrofitting services including auditing, consulting and construction.

New construction offers an even greater potential for energy efficiency as conversation measures are pursued to the economic limit. Hence, the growing proportion of new buildings in the residential housing mix adds greatly to the results obtained in the study. (Post-1978 construction accounts for about 30% of the housing stock in 2000 and 60% in 2025.)

The rate of construction of new units is well within the capacity of the industry. The energy efficiency levels projected here for future years are already cost-effective and in use by some builders. All that is really at issue is the "learning curve" for the residential construction industry, and for the house-buying or renting public.

Compared with improvements in the thermal integrity of the structure, other sources of energy conservation in dwelling units are small. The energy goals for water heating in both new and existing units could be achieved by a combination of simple measures (insulating water tanks) and technically simple devices (low-flow taps), most of which can be installed by the householder. Only with electrical appliances is new technology involved. Rates of improvement of up to 2% per year (compared with the most cost-effective designs available in 1978) are required, provided the improved units are installed in new units as they become available. If the results of the past few years are any indication, such rates of improvement will be achieved (and exceeded) by at least some firms in the appliance industry. Hence, as with construction standards, the only question is whether energy-efficient designs will be purchased by individuals and, more to the point, by developers buying large numbers of appliances at one time.

The Commercial and Industrial sectors need not be treated in detail. In the case of the former, levels of energy efficiency being achieved today are assumed not to become the norm for new buildings until the year 2000, and competition-winning designs available today not until the year 2025. The extent of commercial activity was determined by the LTSM and divided between new buildings and existing buildings on a province-by-province basis. The levels of retrofitting assumed for commercial buildings are already cost-effective and are being exceeded in many cases, particularly where there is an institution, such as a school board, that is both responsible for paying energy costs and short of cash (Brooks and Perras, 1982, p. 30).

In the case of industry, levels of energy efficiency are extrapolated from industry projections and, for the year 2000, are below what some industrialists deem likely (Union Carbide, 1980). Except in a few cases, investments in existing and in new plants were not distinguished. For both sectors overall rates of improvement in energy efficiency of 1% to 3% per year on the average, depending upon subsector, are implicit in the results of the study. It possible that they would be achieved entirely in response to higher energy prices, though government assistance in the financing of energy-efficient plant and equipment would no doubt speed the process. In any event, the gains are within the capability of Canadian industry, which is all that is at issue in this section.

Turning to the Transportation sector, emphasis can be placed on the automobile and light truck subsectors from which the greatest gains in energy efficiency are derived. With the possible exception of heavy trucking, energy efficiency gains in other modes are being implemented more rapidly than projected in this study. For example, the new generation of medium-range Boeing 767 jets being purchased by Air Canada in 1982 are 25% more fuel efficient than the DC-10s being retired, which was the projection in this study for the year 2000.

In looking at the automobile/light truck subsector, there is no question of the industry's ability to produce the necessary vehicles. Saturation levels are reached early in the projection period and only replacements are needed thereafter. As shown in Table 4.3, the number of automobiles and light trucks on the road is projected to increase from 10 million in 1978 to 13 million in 2000 and 16 to 17 million in 2025. The share of urban vehicles (more efficient and powered by electricity, CNG or alcohol) in the fleet shifts from nil in 1978 to 45% in 2000 and 60% in 2025. The number of kilometres driven per vehicle-year varies widely by province. The ranges shown on Table 4.3 suggest modestly increasing driving from East to West across the country, a difference that increases with time. There are only slightly fewer vehicles on the road in any year under the Consumer Saturation scenario compared with Business As Usual, but they are typically driven 20 to 25% fewer kilometres per year. In terms of per capita mobility, this decrease in use per vehicle is largely offset by an increase in the number of vehicles per person.

There may be some question of the industry's ability to implement production runs for urban vehicles that depend upon a variety of fuels. (Discussion of problems related to the substitution of methanol for gasoline engines is deferred to the section on implementing a soft energy supply system just below.) However, electric vehicles and particularly CNG vehicles use many of the same components as standard vehicles. Comparable economies of scale could be achieved by reducing the number of models. The main question is whether the efficiency gains can be implemented at the rate projected in this study. They require an annual improvement in the new vehicles coming off production lines that would average 0.1 L/100 Km (1.5 mpg). The fact that test vehicles with the level of efficiency projected for after the turn of the century already exist indicates that technical problems can be dealt with. Normal turn-over of the auto fleet is more than enough to ensure that the fleet average efficiency changes as projected. Hence, as with appliances, the only question becomes one of whether such energy-efficient vehicles will in fact be produced and purchased.

Supply

In the discussion of energy supply in Chapter 3, a four-fold division was created by classifying sources as conventional or new and renewable or nonrenewable. For the purposes of this chapter, only new sources need be discussed inasmuch as the rates of development projected in this study for of conventional energy sources, whether renewable or nonrenewable, are so much below those in official forecasts that one can infer that they are certainly feasible. In a few provinces (e.g., New Brunswick) our projections for hydropower may be higher than official forecasts because new hydro has been substituted for proposed coal or nuclear stations. However, in all cases the sites are known to be feasible, and the total level of construction activity is below that in the official forecasts.

TABLE 4.3

AUTOMOBILE AND LIGHT TRUCK FLEET, BY TYPE AND USE

A. NUMBER OF VEHICLES (Thousands)

Vehicle Type	1978	Business as Usual 2000	Business as Usual 2025	Consumer Saturation 2000	Consumer Saturation 2025
Urban	N.A.	5887	9872	5734	9478
Non-Urban	N.A.	7271	6692	7072	6251
Total	9860	13 158	16 564	12 806	15 792

B. NUMBER OF THOUSANDS OF KILOMETRES DRIVEN PER YEAR

Region	1978	Business as Usual 2000	Business as Usual 2025	Consumer Saturation 2000	Consumer Saturation 2025
Urban					
Atlantic Provinces	N.A.*	15-21	15-21	11-19	11-16
Ontario & Quebec	N.A.*	18-21	18-19	15-21	15-19
Western Provinces	N.A.*	19-25	19-25	19-21	17-20
Non-urban					
Atlantic Provinces	15-23**	15-30	15-29	11-22	11-23
Ontario & Quebec	18-24**	18-24	18-22	15-24	15-22
Western Provinces	19-31**	19-31	20-31	20-27	20-22
Territories	12-15**	12-15	12-15	11-14	10-12

* N.A.: not applicable

** average mileage for all vehicles

SOURCE: FRIENDS OF THE EARTH SOFT ENERGY PATH STUDY 1983

Peat is the only new nonrenewable energy source to expand in the soft energy futures projected here. Overall the rate of bringing peat into production is quite modest: from nil to just under 32 PJ/a in 2000 and 96 PJ/a in 2025 in Quebec; from nil to under 10 PJ/a by 2000 in New Brunswick and steady thereafter; and from nil to about 30 PJ/a by 2000 in Newfoundland and declining thereafter. Depending upon the thickness and quality of the peat, something between 50 and 100 hectares of land are required per petajoule. This means that, in the case of Quebec, the largest producer, the industry would "mine" up to 3200 hectares per year in 2000 and up to 9600 per year in 2025. The total commitment of land over time would be substantial -- equivalent to about half the surface area of Prince Edward Island -- but assuming reclamation should be easily accomodated within Quebec.

Turning to new renewable energy sources, only those related to biomass need close scrutiny. The projections for the use of active solar systems are not large: 45,000 square metres of collector surface installed and operating in 2000 and 105,000 square metres in 2025. (These requirements are set on the assumption of systems yielding just over 2.5 gigajoules per square metre of collector surface each year, roughly 20% efficiency in converting sunlight to heat.) About two-thirds of that capacity is located in the western provinces. The existing Canadian solar industry already has enough capacity to meet the production requirements of about 2,500 square metres of collector surface per year (starting in 1985). No commercial industry exists today in Canada for solar photovoltaic and wind electric systems (in the sense of being able to deliver off-the-shelf systems at cost-effective prices), but the projected output, hence the needed capacity is small, as shown in Table 4.4, and the lead time is long. The major question for wind and photovoltaic generation of electricity is whether the costs projected for the 100th to 1000th unit installed will in fact be achieved, which requires a reduction to about one-third of current costs for the former and one-tenth for the latter (United Nations, 1980). Given such reductions, there should be no problem introducing the number of units projected here into provincial electrical systems.

Several biomass sources, including municipal wastes and agricultural wastes, make relatively minor contributions to local energy supply in most provinces in the projection years. In such cases, the activity levels, as determined by population and LTSM projections, indicate how much waste is available. No question of implementation strategy would seem to arise so far as the technology or the sequencing of investments is concerned, but it may be that various barriers and incentives, as discussed in Section 4.1 above, need to be adjusted before such sources can be implemented in a cost-effective way.

TABLE 4.4

SIZE OF WIND AND PHOTOVOLTAIC INDUSTRY IN 2000 AND 2025

	Business as Usual 2000	Business as Usual 2025	Consumer Saturation 2000	Consumer Saturation 2025
Projected Output (Petajoules)				
solar photovoltaics	3.10	28.04	3.25	15.65
wind machines	6.96	30.69	6.55	27.78
Needed Capacity* (Megawatts)				
solar photovoltaics	490	4440	5150	2480
wind machines	1100	4860	1040	4400

* Assumes 20% load factor

Canola (a vegetable oil), extracted from rapeseed grown in Alberta and Saskatchewan, is assumed to be used as a substitute for diesel oil. The net quantity projected in our analysis amounts to only 14 petajoules in 2000 but grows to 89 petajoules in 2025 (roughly one-fourth of the output of a tar sands plant operating at full capacity).[1] More could be grown without impinging on land devoted to growing the same crop for food, but a conservative production figure was selected because so little is known about the use of vegetable oil as energy. Because the crushing and refining process is simple, relatively small-scale plants may be cost-effective, particularly to supply the agricultural industry itself. It requires about 1 million hectares to yield a net output of 16 PJ in canola, so some 5 1/2 million hectares of land would be required for projected output in 2025. This is a substantial amount of land, but more than enough could be found in land currently left in summerfallow, which is now recognized to be an inappropriate farming practice (Jensen Engineering, 1981).

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[1] Gross production rates are 10% higher to allow for the energy requirement of harvesting, crushing and refining.

The major source of biomass developed in this study is wood. So far as implementation is concerned, the wood energy industry can be divided into three components. The first involves the use of wood wastes, mainly on-site at plants in the forest industry, but also for sale to other nearby users. The quantities involved are larger than appear in our tables because wood wastes used within a plant appear as a reduction in the demand for energy rather than an increase in supply. (The same is true for agricultural wastes and biogas.) Recognition of the value of mill residues has been growing rapidly, and it is doubtful if, even under today's adverse incentive and pricing situation, there will be any surplus mill residues in the future. In short, no question of implementation arises.

The second component of the wood energy industry involves the production of wood as a domestic and industrial heating fuel. Total biomass solids grow from 210 PJ/a in 1978 to 890 PJ/a in the year 2000 and 980 PJ/a in the year 2025. However, those figures include some waste products (forest and agricultural). Better figures for fuel wood production separately would be 360 PJ in 2000 and 460 PJ in 2025 (240 and 400 PJ under Consumer Saturation), as shown in Table 3.13. Well-managed woodlots in southern Canada should yield each year 10 tonnes of dry wood (about the same as 10 cords) per hectare on a sustained yield basis, and pulpwood thinning about the same. At 20 GJ per tonne, output per hectare-year would be 200 GJ. Allowing 20% of the surface for roads and watercourses, this means that roughly 2 1/4 million hectares would have to be devoted to growing biomass solids in 2000 and about 3 million hectares in 2025 (1 1/2 and 2 1/2 million hectares under Consumer Saturation). The land requirements for biomass solids alone are, therefore, manageable (the surface area of Prince Edward Island is just over half a million hectares), particularly when it is recognized that much of this land will be subject to multiple use. Necessary changes in land use should come about naturally, though there is much that governments could do to smooth the transition, as suggested in section 4.1 above.

Of more concern than land requirements is the necessity to develop a strong wood fuel industry. Assuming that the industry continues to be dominated by small firms, many thousands of such firms would have to be in operation. Much of the wood fuel will have to be converted into chips and pellets to reduce storage and transportation costs and to create a uniform feed for automatic furnaces and boilers. This suggests that substantial development efforts will be necessary, including measures to ensure that capital is available to purchase or lease the necessary equipment. (To suggest an order of magnitude, if each firm supplying wood fuel harvested 225 hectares, some 10,000 firms would be in operation in 2000; and, if each firm required capitalization of $200,000, some $2 billion would have to be made available through public or private channels.) Such efforts will have to be focussed regionally and possibly even locally because of variations in growing conditions, land tenure and markets. However, the task is not large by national standards, and the investment is much less than that proposed in many energy megaprojects.

On the other hand, it may be inappropriate to assume that the wood fuel industry continues to be dominated by small firms. Growing capital requirements, particularly to produce pellets, will give some advantage to larger firms. So too will the shift to industrial use as the main market for wood fuel. Big consumers may well prefer to deal with big supply firms or even to manage them as subsidiaries. Finally, the increased value of wood will translate into increased land values which are generally more easily captured by larger firms.

The final component of the wood energy industry is the one that is most critical for the soft energy futures developed in this study, namely the production of woody biomass to serve as a source for alcohol fuels (defined here as methanol). Questions of environmental damage have been mentioned elsewhere and will be raised again in Section 4.3 below. Here the question is whether a methanol-based transportation sector is feasible. A transition to methanol produced from biomass could be limited by (1) ability to use methanol as a transportation fuel, (2) the need to create an industry to make methanol on a large scale, or (3) the availability of biomass in sufficient quantity. These will be dealt with one at a time.

Given that methanol vehicles already exist in small numbers, and that fleets of methanol vehicles are going into production in Europe (mostly as blends with gasoline but also alone), it is reasonable to assume that any technical difficulties of using methanol efficiently as a substitute for both gasoline and diesel vehicles will be resolved in the next two decades (Shackson and Leach, 1980). Even in the year 2000, the Transportation sector is still more dependent on petroleum than on methanol (substantially more in the Consumer Saturation scenario). A distribution system for methanol would have to be established, but such a system would not differ in any essential respect from that for gasoline as methanol can be transported by pipeline, rail or truck. With technical adjustments made to allow for its different properties (more corrosive, hygroscopic) methanol pumps can exist beside gasoline pumps.

Methanol production itself would not seem to be a problem. The technology to produce methanol from a variety of feedstocks, including natural gas and coal as well as biomass, already exists. Natural gas would be too expensive for this use at projected price levels (Table 2.4). Coal could be used but has been rejected here for environmental reasons. The scale of the required industry is very modest by comparison with conventional alternatives. In Alberta in the next 10 years, for example, two oil sands plants are expected to be built, each yielding 300

PJ/a. Some have even argued that such plants should be built at the rate of five per decade. The most aggressive scenario examined here would lead to production of only 300 PJ/a of methanol in Alberta by the year 2025. For Canada as a whole, about 700 PJ of methanol are required in 2000 and 1920 PJ in 2025, a volume that, as noted in Section 4.1, could be produced in 115 and 315 plants, respectively, each producing 1,000 tonnes per day of methanol. (For the Consumer Saturation scenario, requirements are 10 to 30% less, and the number of plants is proportionately reduced.) Assuming the plants were built at a uniform rate starting in 1985, 9 plants would have to be built every year to 2025. Annual investment requirements (including land) would be $1.5 to $2 billion (cost estimates for biomass-based methanol plants vary widely) exclusive of the distribution system, no small sum but one that will substitute for other investments to produce Liquid Fuel.

The land requirements necessary to provide biomass for the methanol plants projected in this study are substantial. At an average yield of 10 ODt/hectare-year (at 20 GJ/tonne), the primary biomass demands for methanol in the Business as Usual scenario give rise to a total land requirement of 1.0 million hectares in 2000 and 6.9 million hectares in 2025, 1.3 million hectares and 4.6 million hectares respectively in the Consumer Saturation scenario. (These land-use estimates are based on that proportion of methanol production derived from harvested forest biomass, as shown on Table 3.13, adjusted for the energy requirements of harvesting and processing; as such, they exclude methanol derived from mill and logging wastes. For example, in the Business as Usual scenario for 2000, some 114 PJ of methanol is derived from wood harvested for its energy content; after dividing by 55% efficiency, 207 PJ of primary energy are required, and at 200 GJ/ha this requires approximately 1 million hectares of land.) Such figures are of course only indicative. Higher yields (thus lower land use) could be obtained in intensively-managed plantations, but lower yields (greater land use) would be obtained in extensively-managed areas in the northern parts of the province.

As indicated in Appendix 2.5, the availability of land is more than sufficient for methanol requirements on a national basis, though not in every province. The calculations in Appendix 2.5 were based on national land-use surveys which identified 31 million hectares of unimproved but potentially arable land and abandoned farmland. The potential production of methanol from this land area, assuming a wood gasification process, is several times what is required in the Business as Usual scenario in 2025. (Appendix 2.5 also shows comparable calculations for wood to ethanol using acid hydrolysis. Roughly twice as much land would be required to produce an equivalent quantity of energy in ethanol. Both the ethanol and the methanol calculations assume plantation silviculture with 8 year rotations and productivities of 14 oven dried tonnes per hectare-year.)

Appendix 2.5 represents an independent check on the provincial studies, which were done separately and which were generally more conservative in their estimates of both land availability and productivity per hectare. Further supporting evidence is provided by calculations at Forinteck, which show a potential forest production of 8 to 10 EJ using only "accessible" primary and secondary forest and a yield (taking only above-ground growth and allowing for harvest losses) of only 3 ODt per hectare (Graham, 1981).

Except for the Forinteck estimate, the figures in the previous paragraph refer to land requirements for methanol production alone. To these requirements should be added 1 1/2 to 3 million hectares of land required to produce wood fuel and 5 1/2 million to produce vegetable oil. Although each of these energy forms would be drawn from a different land base -- unimproved and abandoned farmland, forests, and agricultural land respectively -- the land-use requirements to "grow" energy cumulate to substantial areas, as shown on Table 4.5 and Figure 4.1. Small perhaps compared with the 540 million hectares of land surface (exclusive of freshwater area) in the ten provinces, but nevertheless impressive. For example, they become one of the largest land uses in Ontario, and in Alberta the land area required for biomass energy (including vegetable oil) in 2025 would be double that currently used for agriculture. Caution is obviously in order when land-use shifts of this magnitude are suggested.

In summary, there does not appear to be anything in the nature of the resource itself, nor in the technology or structure of the industry, that would prevent implementation of a biomass-based methanol fuel industry at the rate projected in this study. A variety of specific programs and policies would be helpful, and in some cases necessary (e.g. fuel-grade methanol standard). However, two policy steps would appear more important at this time: on the demand side, some clear indication is needed from the Federal government as to the role that methanol is expected to play in the Transportation sector over the next several decades; and, on the supply side, a more positive attitude is needed from Agriculture Canada about the possibilities for growing energy on land not needed for food production.

4.3 IMPACTS

Some impacts that would result from following the soft path scenarios developed in this study deserve to be emphasized because they bring out further policy and implementation issues. They will be discussed under the subheadings of economic, social, and environmental, but the lines of division are not very clear. Also, in the abscence of detailed implementation plans, which are beyond the scope of this study, the specification of impacts must remain general.

TABLE 4.5

ADDITIONAL LAND REQUIREMENTS FOR ENERGY FROM BIOMASS
(10^6 hectares)

Form	Business As Usual		Consumer Saturation	
	2000	2025	2000	2025
Biomass Solids	2.3	3.0	1.5	2.5
Methanol	1.0	6.9	1.3	4.6
Vegetable Oil	0.9	5.5	0.7	4.7
	---	----	---	----
Total	4.2	15.4	3.5	11.8

As a background against which to view impacts, Table 4.6 provides indicators of energy use and energy productivity in the economy. All of the terms used in Table 4.6 have been defined before or are self-explanatory with the exception of Required Primary Production. This term attempts to capture the actual amount of primary energy that would be required to provide for the level of secondary use that is the focus for most of the analysis and reporting in this study. It is defined as primary production minus exports plus imports[2] and is roughly comparable with figures in other reports for "primary consumption" or "total energy use." The trends shown in Table 4.6, coupled with those toward greater use of renewable sources of energy and greater provincial and territorial self-reliance (Table 3.9) represent the sources from which the economic, social and environmental impacts derive. What is clear, above all else, is that under either of the scenarios developed here, the economy and each of its sectors becomes substantially more efficient and that, in so doing, a decoupling of the linkages between energy use and economic and population growth is effected. Thus,

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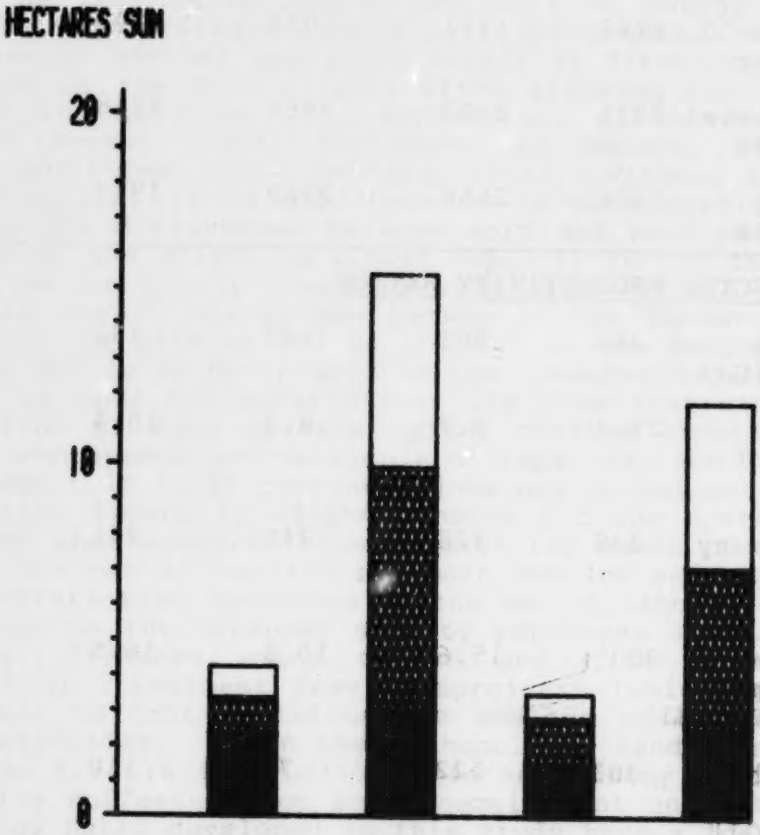
[2] More precisely, Required Primary Production is defined as equal to primary availability less secondary exports plus secondary imports with both of the latter terms adjusted to reflect the implicit requirements of the primary Energy Supply sector. All of the required components of the equation can be read directly from the primary/secondary tables (numbers CA-2 and CA-12 through CA-15).

FIGURE 4.1

PROJECTED LAND REQUIREMENTS FOR BIOMASS PRODUCTION

(MILLIONS OF HECTARES)



BU = BUSINESS AS USUAL SCENARIO

CS = CONSUMER SATURATION SCENARIO

TABLE 4.6

ENERGY USE, PRODUCTION AND PRODUCTIVITY IN 1978, 2000 AND 2025

		Business as Usual		Consumer Saturation	
	1978	2000	2025	2000	2025
PART A: ABSOLUTE LEVELS (PJ)					
Secondary Energy Use	5993	6239	5289	4693	3928
Required Primary Production	7951	10 077	9049	7461	6815
Direct Household Energy Use	2262	1371	1073	1241	930
Direct Industrial Energy Use	2226	3137	2564	2218	1834
Energy Supply Sector Use	1406	2556	2289	1942	1801
PART B: SELECTED PRODUCTIVITY RATIOS					
Secondary Use per capita (GJ)	256	202	143	152	106
Secondary Use per dollar of GDP (MJ)	23.3	9.7	6.3	10.4	6.3
Required Primary Production per capita (GJ)	339	326	245	241	185
Required Primary Production per dollar of GDP (MJ)	30,9	15.6	10.8	16.5	11.0
Direct Household Use per Household (GJ)	303	122	76	110	66
Direct Industrial Use per Worker (GJ)	203	185	133	131	95
Energy Supply Sector as share of Required Primary Production (%)	17.7	25.4	25.3	26.0	26.4

**SOURCE: FRIENDS OF THE EARTH
SOFT ENERGY PATH STUDY 1983**

secondary energy use per capita falls to 55% and 40% of its 1978 level in the Business as Usual and Consumer Saturation scenarios, respectively, while required primary production per dollar of GDP falls to 27% of its 1978 value in both scenarios.

Economic Impacts

Economic impacts have been alluded to at many points above. Some of the expected impacts can be made more explicit, including: (1) employment and inflation, (2) industrial shifts and regional development, and (3) balance of payments.

(1) Soft energy paths of the type adopted in this study generally create more employment and require less capital (hence tend to be less inflationary) per unit of energy produced or saved than do alternative hard path approaches. This is true regardless of whether one looks merely at first-round (on-site) effects or at the full effects after allowing for the purchase of goods and services, the expenditure of income and import leakages (Brooks, 1978; Buchsbaum and Benson, 1979; Victor, Hathaway and Lubek, 1979; Rodberg, 1980). Without specification of alternatives, it is difficult to be more precise about the extent of the differences between soft and hard paths, but the direction of the effect is almost implicit in the changing relative prices of energy compared with other inputs. Thus, the industrial use of energy per person in the labour force falls from 203 GJ in 1978 to 133 GJ in 2025 in the Business as Usual scenario, and to 95 GJ in 2025 in the Consumer Saturation. Comparisons of specific alternatives are also instructive. Thus, construction of each methanol plant creates about 300 person-years of employment per petajoule of capacity, and its operation creates about 10 to 25 permanent jobs per annual petajoule. The construction figure is slightly above and the operation figure much above what would be created with tar sands plants. Reductions in the use of capital are both smaller and more difficult to demonstrate than increases in the use of labour, but they are represented on the consumer side by purchases of smaller equipment (e.g., furnaces, autos, motors) and on the producer side by the shift of investment from megaprojects (which seem uniquely susceptible to cost inflation) to smaller scale and more dispersed activities. Again the methanol-tar sands comparison, as in Section 4.2, is instructive. In an economy that seem to be chronically suffering from both unemployment and inflation, the soft energy paths developed in this study have a lot to offer.

(2) The economic effects of industrial changes and regional development stem from the same sources: (a) the emergence of new industries based on the delivery of energy conservation or renewable energy services; (b) the decline of industries based on the delivery of hard energy sources; and (c) a greater dispersion of the energy industry, including both its production and its conservation components. Outside the energy

industry itself, soft path policies will favour the emergence of firms and industries that can adopt energy-efficient production processes or produce energy-efficient products; those that fail to do either will tend to decline. Such shifts will be reinforced by those already embedded in the LTSM projections for a relative shift of spending from durables to services. The so-called "high tech" industries should fare well under soft path policies.

All the changes will likely have a depressing effect on resource production and on heavy construction but support manufacturing and services. The changes also appear likely to favour smaller scale enterprises over larger, at least in the energy industry, and ironically an energy industry that will be market-oriented rather than resource-oriented in location. (That is, it will tend to locate near population centers as if it were a service industry.) Biomass-based industries are an obvious exception so far as location goes but not scale. Moreover, the resource itself is so widely dispersed in Canada that the biomass-to-energy industries represent only a partial exception. In a modified form such trends should also appear in non-energy industries. At the very least, reduced requirements for energy of any kind and the availability of local, soft sources will reduce the advantages that some firms have had from locating close to a large energy source.

To the extent that inequalities in the distribution of energy resources are a source of regional disparities, the changes cited in the previous paragraph imply that those disparities will be reduced under soft path policies. In particular, local employment should be generated and import leakages (money that flows immediately outside a region to buy energy) should be reduced. Employment has been discussed above. The important of import leakages can be indicated by two examples. In 1978 Quebec spent nearly $3 billion to buy oil alone, of which only a retailing margin and some refining income stayed within the province. In Renfrew County, Ontario (a semi-rural county along the Ottawa River with an average family income somewhat below the provincial average), some $47 million was spent in 1979 for petroleum products of which less than 20% (and possibly less than 10%) remained within the County (Energy Pathways, 1980). In contrast, some 80% of the $1 million or so spent for wood fuel remained within the country, at least for the first round of expenditures.

(3) International trends toward more efficient use of energy have already led to surpluses of energy on world markets. Soft energy paths will likely lead to even greater surpluses. According to the results of this study, Canada will have an increasing surplus of oil, natural gas and electricity. In Alberta current proved reserves of oil (including synthetic crude) exceed projected cumulative demands through 2025 in the Business as Usual scenario. (If synthetic crude is excluded,

current proved reserves fall short of projected cumulative demands, but new discoveries can be expected to make up the difference.) Export projections for natural gas from Alberta can be even more bullish. (Production figures for Alberta beyond those necessary for Canadian requirements were not even projected because reserves appear to be large enough to supply any likely level of export demand.) So can those for electricity, especially from Quebec (including production in Labrador). The projections indicate that Hydro-Quebec's exports (both interprovincial and international), which were 5 PJ (2% of its production) in 1978 could grow in the Business as Usual scenario to 140 PJ (23% of production) in 2000 and 300 PJ (42% of production) in 2025, even if no further capacity is added beyond that already under construction in 1978.

Several implications follow from these projections. First, as suggested above, proposals for investment in new conventional energy supply with the expectation that output will be needed to satisfy domestic markets should be regarded with caution. Second, while nothing in these results suggests that there is anything wrong with energy exports, proposals to invest in new energy plants for export should also be regarded with caution. As other countries improve their energy efficiency and develop soft alternatives, export markets may become equally "soft". Third, efforts should be made to facilitate interprovincial trade in energy whenever such trade would reduce overall energy costs including environmental damage and social disruption. Interprovincial grids and pipelines may be the only types of megaproject that make sense. Fourth, given that surpluses exist, the results presented in this study should be scanned carefully to see whether conventional energy sources (particularly oil and gas from southern Canada and electricity from existing hydro plants) might not be cheaper (again allowing for environmental and social effects) than some of the soft alternatives developed.

Going beyond exports of energy, implementation of cost-effective measures to achieve greater energy efficiency should certainly be reflected in the productivity and international competitiveness of Canadian industry. Such evidence as exists is ambiguous but suggests that, on a sector-by-sector basis, Canadian industry is less energy efficient than that of our major trading partners (Energy, Mines and Resources, Canada, Economic Analysis Division, 1981), a result no doubt of historically lower energy prices in Canada. This gap in energy efficiency (and, with higher prices, economic efficiency) is critical because in many provinces the most energy-intensive industries are also the major exporting industries (as in Quebec where the major electricity users export 64% of their output compared with 46% for industry as a whole). As Japanese and German firms are showing, energy efficiency in production and production of energy-efficient products pays off. Artificially low energy prices lead at best to only a very temporary competitive advantage. Further, in some subsectors, such as pulp and paper or construction, Canadian technologies to conserve energy could well become another product of value on international markets.

Social Impacts

Any policy or policy changes creates a chain of social impacts which are difficult to identify and among which it is difficult to make trade-offs. The soft energy scenarios developed in this study are no exceptions. They tend to support urban as opposed to suburban living, cultural diversity, and, by implication at least, greater frugality and what might be called an "environmental consciousness". Conflicts over areas subject to native land claims would be reduced. Opportunities for local self-reliance and for small business would be enhanced (both are social as well as economic effects). No doubt lots of other social impacts can be identified. However, the one that is perhaps of most immediate importance involves the distribution of income: How will the scenarios described in this study affect lower income people?

From a general point of view, it is accepted that energy conservation will be relatively more helpful to lower income people because they spend a greater portion of their income on direct energy purchases. More specifically, one can look at the relationship between direct energy purchased by an average household and total secondary energy used per household. The direct energy used by the household consists of the space and water heating energy, the electricity used and the fuel for the automobile. In 1978 these energy uses per household were 150 GJ, 20 GJ and 133 GJ respectively for a total of 303 GJ. Total energy use per household in 1978 was 802 GJ so that direct energy use represented 38% of total energy. In 2025 in the Business as Usual scenario the corresponding direct energy uses were 37 GJ, 10 GJ and 28 GJ per household for a total direct energy use of 75 GJ per household. Total direct use in the Consumer Saturation scenario is a bit lower at 66 GJ per household with the difference made up entirely of differences in automobile efficiency and use. Total energy use per household in 2025 is 373 GJ in the Business as Usual scenario and 277 GJ in the Consumer Saturation so that direct energy purchase represents 20% and 24%, respectively, of the totals. This sharp reduction in the fraction of energy which is purchased directly by householders reflects the fact that these energy uses offer a high and immediate potential for conservation. By implication, householders will be able to shield themselves from the rising costs of energy by taking appropriate steps. Indeed, for the Business as Usual scenario, the direct energy use per household declines by more than a factor of five while the energy costs rise by factors of two to three. Thus, the real cost of direct energy per household in this scenario declines to something like one half of its 1978 value by the year 2025. This saving will be partly offset by the increased cost of the houses, appliances, and (possibly) automobiles, but the analysis does illustrate that energy expenditures can decline significantly even when energy prices are rising.

Despite the advantages of soft paths for the general distribution of income, it would be silly to maintain that no one would be injured or, more particularly, that none of those injured would have inadequate incomes. Problems could arise from time lags between the impact of higher energy prices and the effectiveness of conservation programs, from capital barriers that limit the opportunities to save energy, from institutional problems as for tenants in inadequately insulated buildings, from employment losses as megaprojects are cancelled and industries relocate and from land-use changes. Efforts should be made to identify such impacts and to develop programs to offset them. Proposals to keep energy prices down in order to avoid injury to low-income Canadians are misguided, but programs that focus on those who are specifically disadvantaged by higher prices are to be recommended.

Environmental Impacts[3]

With the exception of biomass harvesting, there is no question but that short-term and long-term environmental threats would be greatly reduced under the soft path scenarios developed in this report as compared with harder alternatives. Indeed, given the widespread and serious environmental damage that stems from almost any form of energy production, a reduction in damage will result from any set of energy policies that reduces the demand for energy. In this study there is no Arctic production of any kind; the use of coal grows only a little (and none of it is converted into liquids); synthetic energy from fossil fuels also grows little; and of course nuclear power plants are completely phased out. Of the fossil fuels, only natural gas plays a strong role in these scenarios, and it is the one that is least environmentally threatening. Together these changes, coupled with improved combustion techniques, promise a reduction in acid rain, no increase in carbon dioxide, and lower sediment and chemical loads in water courses. In addition, the need for certain contentious forms of land use, such as northern pipelines and very high voltage transmission lines, would be reduced compared with the situation under higher energy growth. The specific conservation measures proposed in this study, including more energy-efficient buildings and more efficient vehicles, are not without their own problems. However, in every case that we have been able to identify, those problems are subject to rather simple technical solutions. (Adequate ventilation with heat exchangers prevents the build-up of indoor pollutants in tight buildings, and improved vehicle design reduces the safety hazard of mixing small and large vehicles on the road.) Moreover, many of the measures save materials as well as energy, as with improved motors and smaller vehicles. In short, conservation of energy is not only the most cost-effective but also the most environmentally sound source.

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[3] To a considerable extent, the term environmental impacts can also be used to cover occupational health and safety effects as well.

Just as with energy conservation, some of the energy sources on which these soft path scenarios rely have their own problems. Notable are peat bogs, which must be harvested cautiously and which must be reclaimed after harvesting. Appropriate techniques are well known in Ireland and Finland where peat is harvested extensively. Hydro development is always a threat to natural ecosystems and to heritage rivers. While a number of additional hydro projects are projected in this study, such development is far less extensive than in most other energy studies. (The bulk of the increase in hydro-electricity shown in this study represents projects such as James Bay in Quebec and Revelstoke in British Columbia that were under construction but not in operation in 1978.) No heritage river is taken, nor is any development required in the northern parts of the provinces (where native land claims as well as wilderness values call for caution). Solar heating, solar electricity and wind electricity each require rather large volumes of materials per unit of energy production, but in use they are relatively benign. Technical fixes can deal adequately with local problems such as reflection or noise. And, finally, some soft energy sources yield a net reduction in environmental damage because they use waste products. Notable in this regard are the use of municipal waste as a source of heat and animal wastes as a source of biogas.

The situation with biomass is more worrisome. (Exceptions include the shift of land from summerfallow to rapeseed and the use of mill residues, both of which would offer net environmental benefits.) Harvesting wood as a residential and industrial fuel at the quantities required, the intensive management of forests as a source for methanol (perhaps in combination with pulp wood or timber), the collection of forest residues (such as weed species, slash etc.) and particularly the development of wood energy plantations need careful attention. Good environmental management must be associated with the growing, harvesting and collection of this biomass. (Once collected, the processing of the biomass takes place in mechanical or chemical plants that do not involve any new or unmanageable environmental problems.) Soil erosion, excessive runoff and nutrient depletion could result from poor practices as could all of the problems associated with heavy use of chemicals, fertilization and monocultures. Policy consideration must also be devoted to land use. While there is adequate land available on which to grow sufficient biomass for the needs identified in this study (Section 4.2 and Appendix 2.5), there are at least two further questions: First, is it desirable to devote that much land to growing energy? Second, what are the longer term implications of the land-use shifts implicit in our results? For example, this study was careful not to take any land already in use by the forest or the agricultural industries, but that does not mean that such land would not shift to energy crops once the harvesting of biomass for energy came to be profitable. The higher land values from silviculture for energy are also bound to have efficiency and equity effects that need to be understood early in the process.

There is evidence that biomass can be harvested on a large scale without environmental damage (Holdren et al 1980; Flaim and Hertzmark, 1981; Beale and Heeney, 1981). Moreover, the implementation of biomass sources in this study has been deliberately kept slow. A few decades of research, development and demonstration should provide the time necessary to ensure that environmentally appropriate management and land use practices can be and will be available. As always, the real question is probably not whether such practices will be developed, but whether they will be followed.

CHAPTER 5: SUGGESTIONS FOR FURTHER WORK ON SOFT ENERGY PATHS IN CANADA

In the course of preparing this study, a great deal was learned about methods for undertaking regionally disaggretated soft path analysis and about gaps in information that limit the extension of the results. This chapter will focus first on the need for further research on methods and on soft paths themselves. It is written mainly for those who are contemplating additional work on soft energy paths and who may wish to adopt our approach. Other readers may choose to skip this chapter and go directly to Chapter 6, Conclusions.

5.1 METHODOLOGICAL PROBLEMS

Data Limitations

Any soft energy study will encounter at least two types of data limitations: those related to the inadequacy of data collection, and those related to the unavailability of confidential data. Dealing with inadequacy first, it must be recognized that standard statistical sources on energy in Canada have improved over the past few years. (Compare Statistics Canada Catalogue 57-003 with the older 57-207 and even the 1979 edition of 57-003 with that for 1978.) Nevertheless, they still have serious shortcomings for energy analysis. First, there is no consistent set of end-use categories for energy that can be related to use by sector and to form by quality. What is needed is a functional display of energy data that would distinguish, for example, the electricity used for appliances from that used for water heating in the Residential sector, and the natural gas used for heating from that used as a process input in some industry. This is perhaps the single most serious limitation on detailed analysis of the technical potential for conservation and renewable energy. Second, neither the energy required to produce energy nor that required to transport or transmit it is consistently treated. Third, consuming sectors are too aggregated; broad categories such as "commercial" appear as but a single line, even though they incorporate highly diverse activities. Fourth, it is difficult, and in some cases impossible, to reconcile data in one Statistics Canada publication with those in others. As a result, one is typically at a loss to establish the linkages between energy usage and the activities that are responsible for that use. Finally, for certain energy uses and sources, such as residential wood use and other "non-market" energy forms, data are simply lacking altogether.

The problem of statistical inadequacy is going to get worse with changing energy technology. As on-site and local soft sources begin to play greater roles, it will become more and more difficult to collect consistent data -- as, for example, on energy sources originating as waste products or as waste heat. Even today cogeneration is awkwardly treated. Statistical agencies will have to operate on a ridge between ignoring some energy inputs because they don't look like energy and double-counting others as they cascade from higher to lower quality uses. Imagination in collection and presentation of data will be necessary -- we feel that the tables in this report make a good start -- but at present the statistical system to do better soft energy anaysis is simply not in place.

If statistical gaps are annoying to the researcher, confidentiality of data is infuriating. In some cases, statistical agencies operate under legal strictures that prevent them from releasing data about individual firms. (Statistics Canada will not release any statistics when there are three or fewer firms involved.) Such caution is perhaps understandable when it involves financial data but much less so for physical inputs and outputs, such as energy. In most cases the firms involved will release the information upon request, but this is time consuming and the researcher can never be sure that data from one firm are consistent with those from another.

Statistical confidentiality is not a great problem when dealing with Canada as a whole -- there are generally more than three firms in any sector or subsector -- but it is serious at the provincial level. In some provinces the great bulk of industrial energy data is unavailable for reasons of confidentiality. Again, the problem is going to get worse, for, as noted below, one direction for soft energy studies in the future is toward smaller geographic units of analysis (regions, cities), and here offical confidentiality could simply prevent analysis.

Even less explicable than such official caution is the reluctance of some groups to discuss energy intensity. As mentioned in Chapter 2, the refusal of the Industry Task Forces on energy conservation to provide base line information about past levels of energy intensity made it impossible to deal in a fully consistent way with reported and projected gains in efficiency. The rationale may have been to prevent comparison between sectors that had differing characteristics or even to protect those sectors doing less well than the average, but in either case it was misplaced.

One further lesson from the experience of this disaggregated study: it is critical that a resident of each political jurisdiction under study be involved in the work on that jurisdiction. In many instances statistical data and even information on the results of specific measures to conserve energy were available but had to be "discovered". The data had been collected by individual departments or managers, and, while finding them was time consuming, it was time well spent both in improving the quality of analysis and in building interest in the study.

Need For Computer Models

Once a soft path framework is established for some area, it is generally possible to express that framework as a series of equations and thus develop a computer model that can test the importance of different assumptions, new technologies and different implementation strategies. Computer models can also help in developing the main results.

All backcasting studies face the difficulty, mentioned in Chapter 2, of projecting a future that does not bias the results for or against soft paths. The materials balance approach used in Statistics Canada's Long Term Stimulation Model (LTSM) deals well with this problem. In particular, it avoids the problem of basing results on the price and income elasticities that are just what are subject to change with implementation of soft path measures. While use of the LTSM is restrictive in some ways, it is not clear that further work to introduce, say, different energy supply systems would have been very instructive. The LTSM operates at a fairly aggregated level of analysis, and our approach of grafting onto it specific cost-based energy conservation and soft supply technologies probably pushed the capability of the model about as far as it should be pushed.[1]

Computers could also help in the national integration. In principle, the idea to add 12 regional tables algebraically to create one national one sounds straightforward, but in practice an enormous number of problems can arise. Much the same can be said for programs to compile and check the data going into standard figures and even to produce the figures themselves (as with the bar charts in this study which, once data files were established, could be drawn by the computer). In addition, some regions were importers, some exporters, others both importers and exports (as with importing crude, refining it and exporting RPPs), and still others transhippers. In future studies it would be worthwhile to build programs to do the algebraic addition of the provinces and territories of Canada, and also to make the appropriate adjustments in the Energy Supply sector required by these flows and indeed by the demand analysis itself. If the latter were available on-line, analysts could review quickly the options for supply in energy to a deficit region or using the energy in a surplus region. As it was, only a few options were considered, and those only at a time when all of the provincial analysts were, literally, sitting around a table. Finally, programs to add and check the large number of individual tables and figures from each province, and to ensure they matched with other tables, would have saved an enormous number of hours of detailed (and frustrating) hand work.

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[1] Since this study was undertaken, the Structural Analysis Division of Statistics Canada has developed a successor to the LTSM, called the Socio-Economic Resource Framework (SERF). SERF is a long-term simulation model of the Canadian economy which incorporates a number of detailed energy end-use models in such a way as to make it very useful for the kind of analysis undertaken for this study.

The energy requirements of the energy supply industries proved particularly difficult to handle as every change in the volume or type of flow required adjustments in exporting, importing and transhipping provinces. (There is an irony here in that a study which was intended to focus on secondary energy requirements found its most complex computational problem in calculating the needs for primary energy.) The only other soft energy study of which we are aware that incorporates bottom-up geography as well as bottom-up energy use is one that integrates the three Scandinavian nations, and this not only has fewer pieces but involves no transhipment (Sorenson, 1981). In making a 12-region integration, we feel that we have broken new ground, but in retrospect a computer program designed to make the various mechanical adjustments (e.g., the extra gas that has to be produced in Saskatchewan to pump natural gas from Alberta to Manitoba) would certainly have been welcome.

Operating a Decentralized Study

Analytically Canada is anything but easy. The range of energy supply and demand conditions among and within the provinces and territories is enormous. Among them, annual energy use ranges over two orders of magnitude, as does population and industrial output. (Even ignoring Prince Edward Island and the two Territories, the ranges are more than one order of magnitude.) Climate, geography and economy, to say nothing of energy conditions, are equally diverse. Maintaining a common base of analysis and projection for the 12, while, at the same time allowing a maximum of opportunity to be creative in adapting to the diversity, was a major yet an essential task if the regions were to be integrated into one national total.

There are no magic solutions to the problem of working in a decentralized way. In retrospect, more money should have been allocated for travel, particularly for regional meetings, and telephone contact should have been more frequent. (Three national meetings of all analysts were held as was one additional meeting in each region over a two-year period.) Also, more time and money should have been allocated for reworking the provincial and territorial reports after they were first produced and both new ideas and inconsistencies identified from comparison with other reports. Obviously, it would have been ideal to have had at the outset a firm idea of what the final product would look like, including each of the final tables and figures, but these were changing as the study progressed and as ideas were brought to the national meetings by provincial and territorial analysts. Inevitably, there was a tendency for individual analysts to adjust the approach or the format for presentation of results to reflect better the unique conditions of her/his own region. The former could generally be accomodated, but the latter could not (all standard tables *had* to be identical if they were to be added up). Efforts were made to revise the approach, the conventions and even the format as the study progressed, but in many instances it seemed that responsiveness to a proposal to resolve problems in one part of the analysis or for one region created problems in other parts of the analysis or in other regions.

Further, without elaborating on the point, it is worth noting that decentralized studies magnify problems of presentation. In writing, every generalization is subject to that many more qualifications and exceptions, and it becomes difficult to avoid repetition. The option selected for the preparation of this report--one volume containing methods and national results and a separate volume containing provincial and territorial results---avoids excessive repetition but at a cost: the national write-up cannot be very detailed and the regional ones are not self-contained. In addition, an extra dimension is added to every table and the number of figures to be displayed increases enormously, both of which items can become budget as well as presentational problems.

Finally, there is an important methodological point to be made. Because of the fact that everything cannot be varied simultaneously, soft path studies that operate from a geographically decentralized base will inevitably be less detailed in other aspects than aggregated studies. In part this is because the need for an integrating model will constrain certain degrees of freedom that would otherwise be left open. In part it is also because the time and money devoted to pursuing geographic disaggregation will simply not be available for sectoral or fuel disaggregations. And in part it is a result of the need for simplifying assumptions that, following accepted soft path practice, generally lean against soft path options. As a result, *studies that operate in a geographically decentralized way will tend to be more conservative in their final results than those that operate out of a single office*.

Obviously a balance has to be found between too much and too little flexibility in the coordination of a decentralized study, but that balance is elusive. Perhaps all of the frustrations of undertaking a decentralized soft energy study can be summed up in the words of one analyst who, near the end of the study, exclaimed: "Nothing -- absolutely nothing -- about this study was simple!"

5.2 RESEARCH NEEDS

As one result of completing this study, a number of directions in which soft path analysis should be pursued in Canada have been identified. In at least one area, implementation strategies, a major research effort should be undertaken if the usefulness of this study is to be maximized.

Some Gaps to Fill

Dealing with the more limited studies first, an important direction for future soft path studies will be the analysis of smaller geographic areas: regions, cities, towns, even neighborhoods. Some such studies have been done in Canada (Energy Pathways, 1980) and elsewhere. Though they are subject to instability (one new plant can make a big difference), they do indicate what compact areas with, generally, a limited set of both problems and resources, can do. The first step involves regional or local energy audits to see just how much energy is being used, by whom and for what -- exactly the same sorts of information that comprised the first step in this study.

There are also a couple of economic and technical problems that need further investigation to complete the picture of soft energy futures in Canada. One involves the integration of centrally generated electrical systems with locally produced energy. The problem breaks down into two versions: one where the centrally generated electricity is providing back-up heating when solar, wood or simply retained heat, among other sources, are inadequate; the other where the centrally generated electricity is providing back-up electricity to photovoltaic cells, wind machines or cogenerated electricity when they are inadequate. Studies of the former problem have variously concluded that integration is a problem even if back-up heating can be done at off-peak hours, or that integration is not a problem provided that back-up heating can be done at off-peak hours. As for the latter problem, such studies as exist suggest that peaking problems could be serious unless the central utilities manage the decentralized systems, which is almost a contradiction in terms. Obviously, further study is needed.

In this study no specific form of energy was identified to fuel the air transport subsector. Such a gap was possible because the volume of energy required was small enough to be provided within the excess capacity built into the sources projected for the years 2000 and 2025. The options range from continued use of conventional petroleum fuels through a variety of alcohols to liquid hydrogen. Further study should be capable of narrowing the range of options, if not defining the optimum one.

Still another problem area for soft energy futures involves the provision of high-quality industrial energy. Most of the industries that require large amounts of high-temperature heat or electricity produce primary products, which is why the problem is so important in Canada. Some can use waste products as fuel but for others, notably those involved in the production of primary metals, this does not appear to be possible. While the best way to reduce the demand for this high-quality energy is to encourage recycling, Canada's specialization in primary metals means that fairly large quantities will continue to be required, and further study is needed to determine how best to supply such energy in a soft energy future.

A broader problem is the need to go beyond generalized statements about expected gains over time in industrial energy efficiency to explicit linking of conservation actions to energy savings. Just as we know in some detail how investment in specific measures in building construction will reduce energy use, so we need to know how investment in, say, insulation of heating tanks will cut energy use in some industrial subsector. Obviously, the situation is more complex in industry, but, given the growing share of total energy use to be taken by industry, generalization will not be satisfactory for long.

Of all the economic and technical problems that remain, none are so intriguing and so difficult as those associated with transportation. In almost every soft path analysis, regardless of country, the provision of portable fuels for road transportation turns out to be the most difficult problem. Canada was no exception, and neither were any of the provinces with the exceptions of Alberta (which will continue to have oil well into the next century) and British Columbia (which has so much forest biomass that it could shift completely to alcohol fuels whenever it chose). In some areas no full resolution of the liquid fuel problem is evident, and continued imports from other provinces seem inevitable (a result which is hardly surprising given the diversity of the country). The two Territories and most of the Maritimes fall into this group. In all other ares, the problem is more that of selecting one or a few routes out of many possible options, for the very mobility which road transportation creates requires that a system be developed to produce and deliver the same fuel across wide areas. However, a great deal more analysis is needed prior to taking long-term decisions in Canada about alternative patterns of transportation use and alternative sources of fuel supply. By no means all of the options are soft. Competing with decentralized production of methanol or ethanol are synfuel plants and nuclear-based hydrogen with continued use of conventional petroleum fuels also conceivable. In between are such options as methanol-based hydrogen, compressed natural gas, electricity and others. Each fuel system entails different regional effects, different industrial effects and different environmental effects. In addition, we have assumed that different cities could optimally choose different fuels for local fleets. This assumption has implications for the nature of automobile production that need investigation.

Equally important, modest changes in the location of industry and urban form would reduce the need for transportation and maybe have a bigger effect than vehicle efficiency over the long term. Clearly, there is a great need for analyses of the conjunction of fluid fuel source and transportation system.

Implementation: The Missing Link

Better information in all of the areas mentioned above would be helpful. However, neither individually nor collectively do they represent the major gap remaining in the picture of soft energy futures for Canada. The missing link is implementation. This study has shown for Canada, as other studies have shown for other countries, that soft energy paths are feasible, and likely preferable, compared with hard path alternatives. However, the study has not shown in any detail how to get onto a soft energy path nor has it investigated the implications of following specific paths. Once feasibility is demonstrated, soft energy paths should stand or fall, just as should their hard counterparts, on their social and political, not their economic and technical, characteristics. Hence, further research should focus on the suggestion that soft energy paths would be more socially and politically attractive than the alternatives (Morrison and Lodwick, 1981). For example, some work has been done on the employment impacts of soft paths and on possible impacts on industrial structure in Canada (Brooks, 1978), but, among other things, information on quantity of employment needs to be supplemented with that on the quality of employment; information on industrial structure needs to be linked to that on local and regional development; efficiency calculations need to be supplemented by examination of equity effects; and the capital requirements of different systems need to be compared.

Further research on the implementation of soft energy paths should also focus on implementation mechanisms at both the national and the provincial levels (and possibly at the regional and municipal levels as well). A huge variety of measures is available ranging from information and education programs at one end through pricing, taxing and subsidy schemes in the middle to regulations, restrictions and mandated changes at the other. Some are almost costless, others very expensive; some operate at the national level, others at the individual; each entails unique benefits and costs for different sectors, regions and groups in society. How should we choose among the available mechanisms to select those that would be most efficient and, at the same time, balance the goal to resolve energy problems with the need to preserve our concepts of democracy and of social justice in making the transition? The very nature of a soft path indicates that different mechanisms will be appropriate for different uses and different users, and that programs conceived at the national or provincial levels will have to be adapted for effective local delivery, but such considerations merely strengthen the case for careful selection among alternative implementation mechanisms.

In sum, both the goal of a soft path itself and the means required to attain it must be tested against social and political goals for Canada and for each of the provinces and territories. The information needed to make those tests is far from complete--but neither, it should be emphasized, is it any more complete for hard energy paths. Further research on both soft and hard energy paths probably offers greater returns from exploration of the economic, social and political consequences of implementation than from development of better technologies or more scenarios.

CHAPTER 6: CONCLUSIONS

6.1 THE POTENTIAL

This study investigates the potential, in Canada and in each of the provinces and territories, for energy policies that are based on the principles of "soft energy paths" -- that is energy policies that are based primarily upon the development of energy conservation and renewable energy sources -- over the period from 1978 to 2025. The results of this study can be summarized most briefly as follows: Under conditions of strong economic growth (an increase of more than 200% in gross domestic product) and moderate population growth (an increase of over 50%), it would be technically feasible and cost-effective to operate the Canadian economy in 2025 with 12% less secondary energy than it requires today, and, over the same 47-year period, to shift from 16% reliance on renewable sources to 77%. In addition, should the economy grow by "only" 140% to 2025 (with the same population growth), and should the real cost of soft technologies drop slightly, it would be feasible and cost-effective to use 34% less secondary energy in 2025 than in 1978, with 82% of that energy provided by renewable sources. Over the study period, energy use per capita falls to between one-half and two-fifths of its level in 1978 (Figure 6.1), and energy use per dollar of gross domestic product to just over one-quarter of its level in 1978 (Figure 6.2). Thus, Canada would become enormously more energy efficient over time.

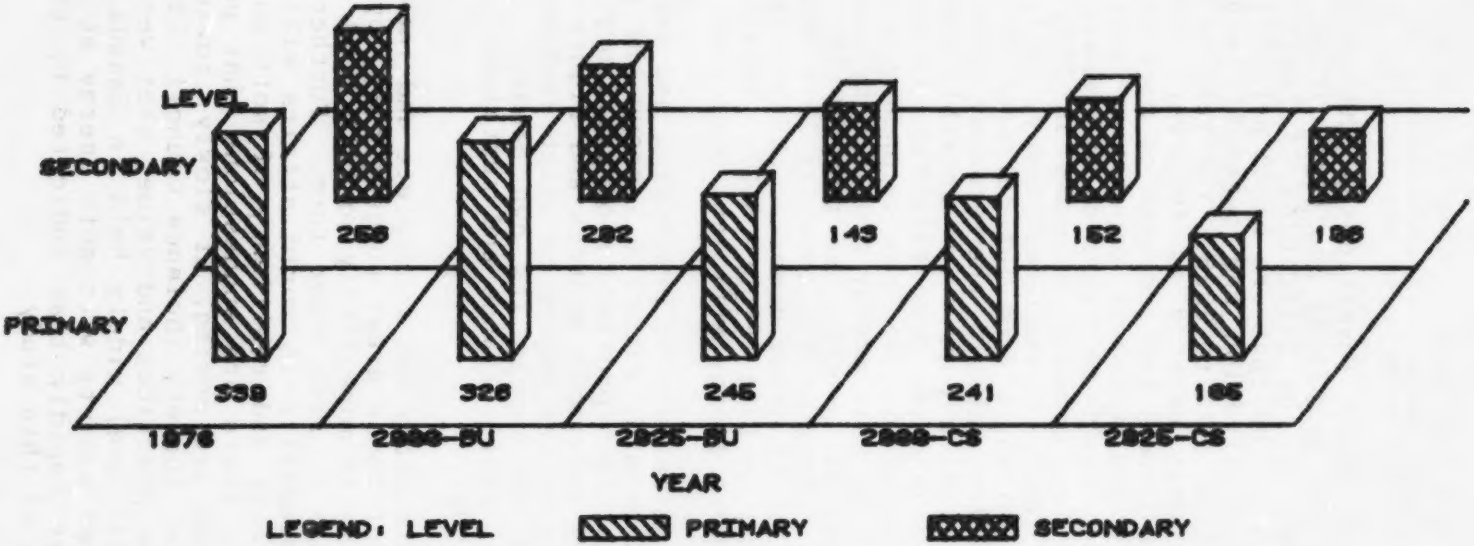
With respect to provincial and territorial patterns of supply and demand, Figure 6.3 shows the substantial growth in the amount of each province's or territory's production that is supplied by renewable sources and Figure 6.4 illustrates the large increase in the degree to which each province or territory would be able to supply its own needs. This potential growth in regional self-reliance and sustainability is a major finding of this study.

This study was incomplete and inexact in numerous areas. A survey of those areas suggest that, by and large, energy demand in Canada is more likely to fall below the projections developed here than to rise above them. Further, the growing uncertainty and instability in world affairs will favour systems with the flexibility and resiliency of soft energy options. And still further, there are suggestions that preferences and lifestyles in Canada are moving, if slowly, toward those appropriate to a conserver society (Science Council, 1977). Certainly be adopting some practices and values that were at one time (and probably still are) widely held in Canada, we could move toward a conserver society with soft energy at its base more extensively and more rapidly than indicated by the relatively constrained results of this study.

FIGURE 6.1

PROJECTED PRIMARY AND SECONDARY ENERGY USE PER CAPITA

(GIGAJOULES)

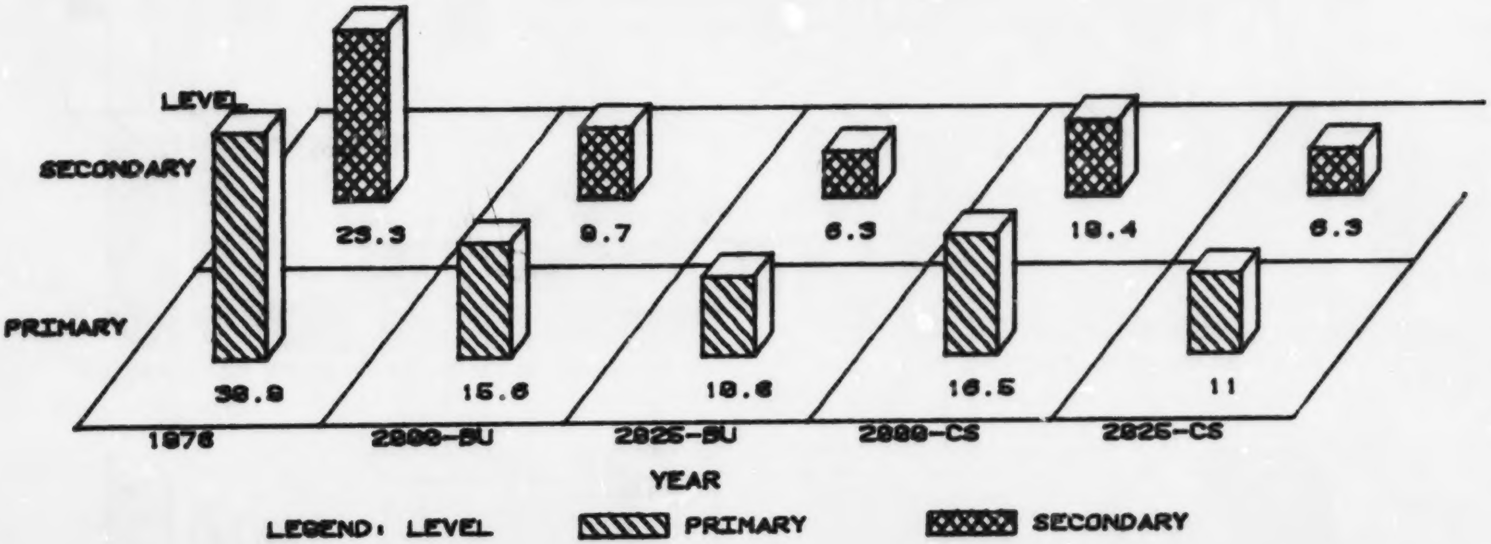


BU = BUSINESS AS USUAL SCENARIO

CS = CONSUMER SATURATION SCENARIO

FIGURE 6.2

PROJECTED PRIMARY AND SECONDARY ENERGY USE PER DOLLAR OF GDP
(MEGAJOULES)



BU = BUSINESS AS USUAL SCENARIO

CS = CONSUMER SATURATION SCENARIO

FIGURE 6.3
PROJECTED DEPENDENCE ON RENEWABLE ENERGY BY REGION

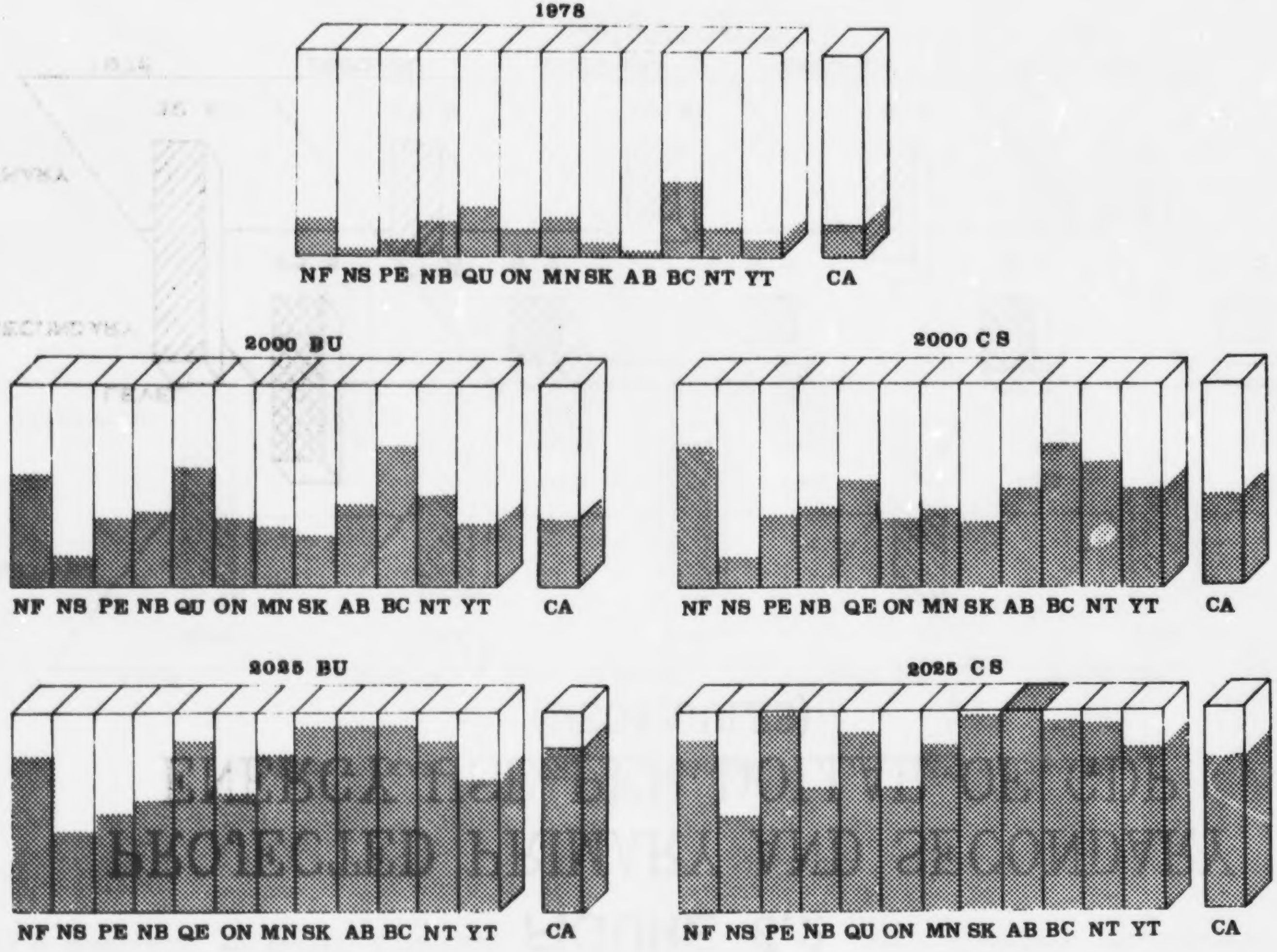
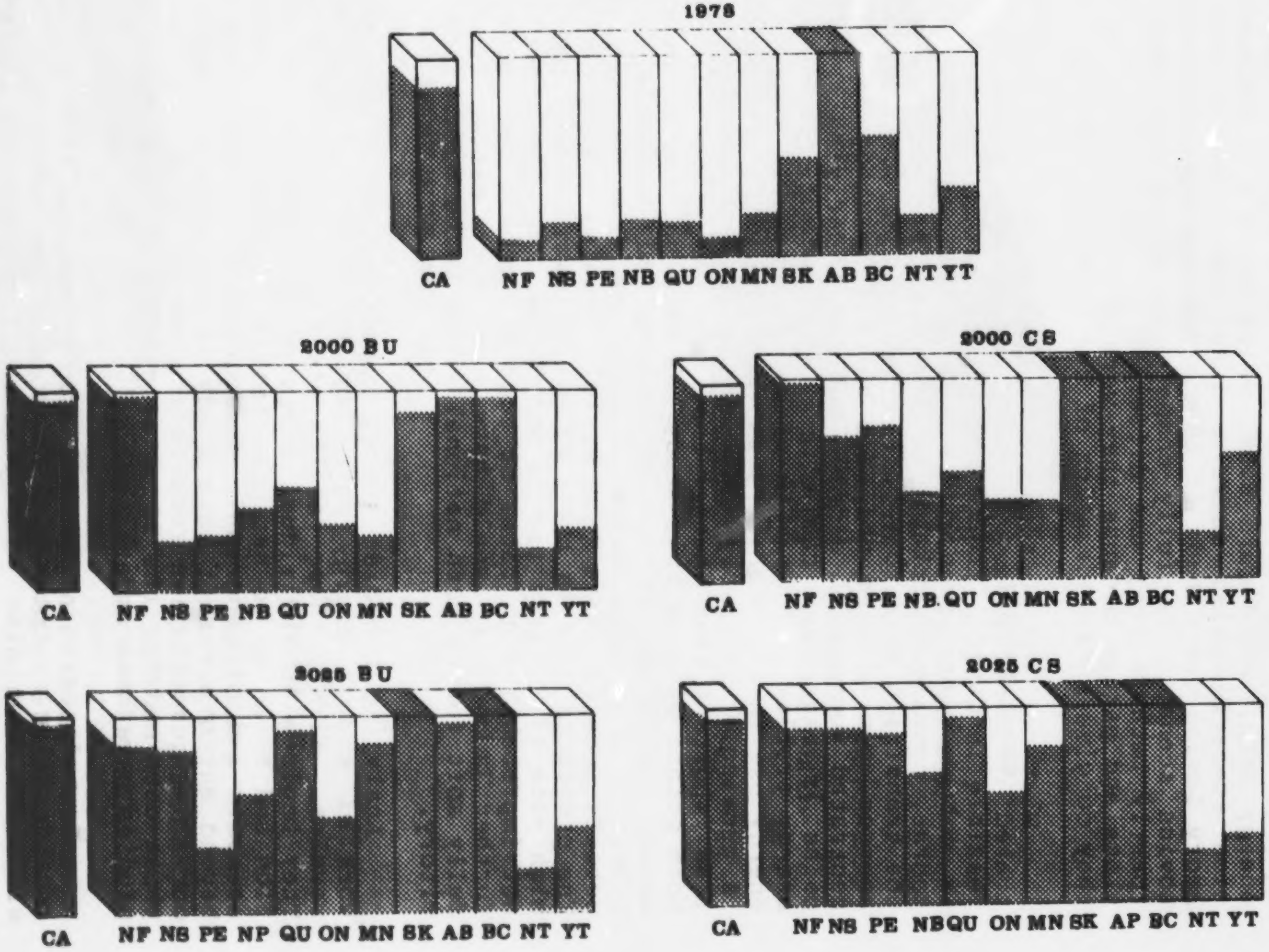


FIGURE 6.4
PROJECTED ENERGY SELF-RELIANCE BY REGION



The national shifts in the use and sources of energy that would result from adopting policies for the soft path options described in this study are illustrated in Figures 6.5A and 6.5B. For comparison, Figure 6.5A, which shows our Business as Usual scenario, also shows a long-term scenario developed at Energy, Mines and Resources that opts for a relatively hard energy path, and Figure 6.5B, which shows our Consumer Saturation scenario, also shows a long-term scenario developed by Amory Lovins for Canada in 1976. While neither the EMR nor the Lovins scenario is fully comparable with those in this study (partly because they use different economic population projections and partly because they were done several years earlier), they do give some indication of the range of previous analyses.

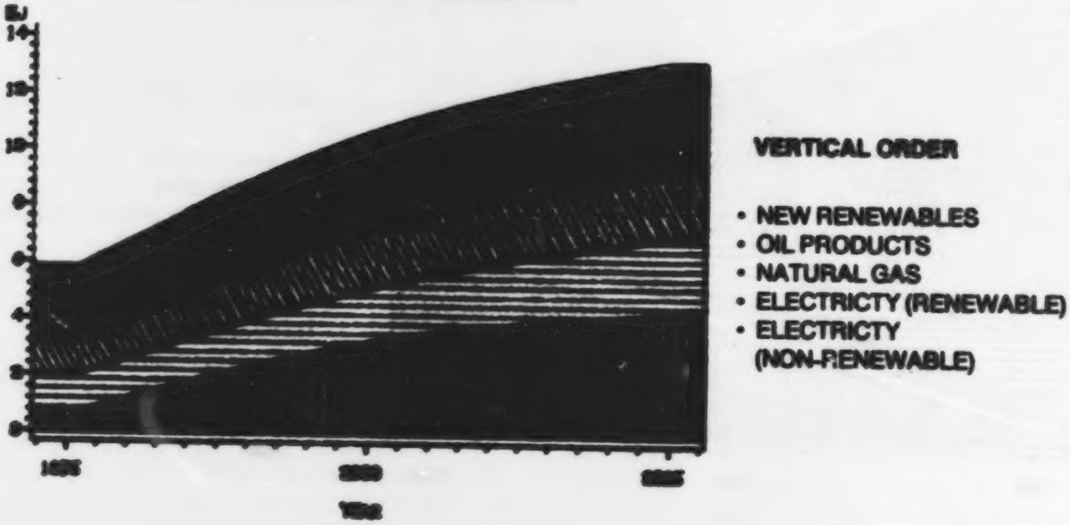
What one can conclude from this study, and what is illustrated in the figures, is that soft energy paths are entirely feasible in Canada, though the transition from today's hard path is not complete even after nearly 50 years. There is, of course, nothing improbable or inappropriate about the length of the transition to a soft path. Not only are conventional energy sources used because they are relatively cheap and highly concentrated sources of energy, but the underlying thesis of soft paths is that they can effect a permanent resolution of the energy problem. Thus, the share of renewable sources in total energy use in any year is less important than whether that share is growing. Similarly, the rate of energy use in any year is less important than whether that rate has stopped growing. From both points of view this study has been successful in an overall sense; annual energy use is falling and renewable sources are providing a greater share of that use from year to year. In detail, some of those "successful" results create new problems. The provinces vary in their progress toward a soft path, and the high rate of biomass use is worrisome. On the other hand, had not improbably high rates of economic growth been accepted (see further below), it would have been much easier to develop a fully soft future both nationally and in each province and territory.

Analyzing Canadian energy opportunities within the framework of a soft energy path implies several things about the results. First, those results are based on bottom-up analysis. They begin with individual units of consumption and of production and build up to national totals. Indeed, in the extent of economic and of geographic disaggregation, this study has gone beyond any other soft path study of which we are aware (though our final quantitative results are not strikingly different from those obtained for the 20 or so other countries where soft path studies have been undertaken).

Second, certain possible energy options were excluded from consideration. Options were sought that were not just more efficient, but also more decentralized, smaller in scale and environmentally less damaging than those typical of today. In

FIGURE 6.5A
ALTERNATIVE ENERGY FUTURES FOR CANADA – PART I

A. LONG–TERM ENERGY ASSESSMENT PROGRAM
ENERGY, MINES AND RESOURCES, 1978



B. BUSINESS AS USUAL SCENARIO
FRIENDS OF THE EARTH, 1982

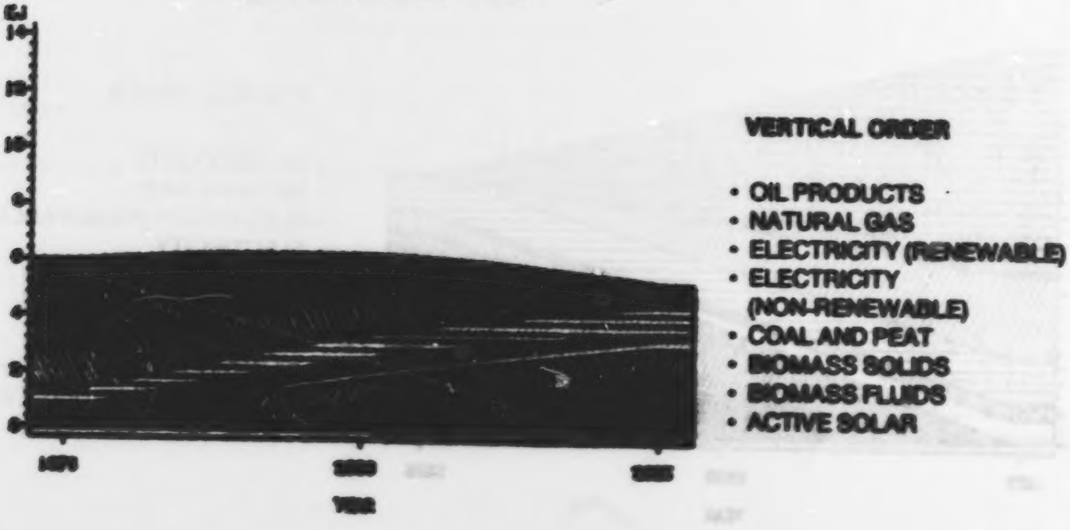
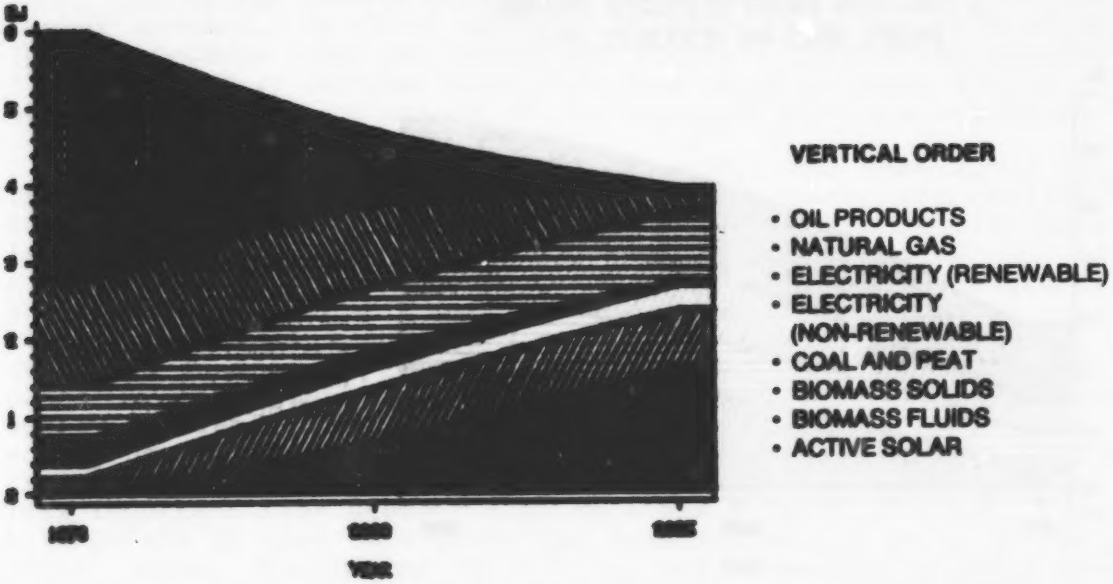


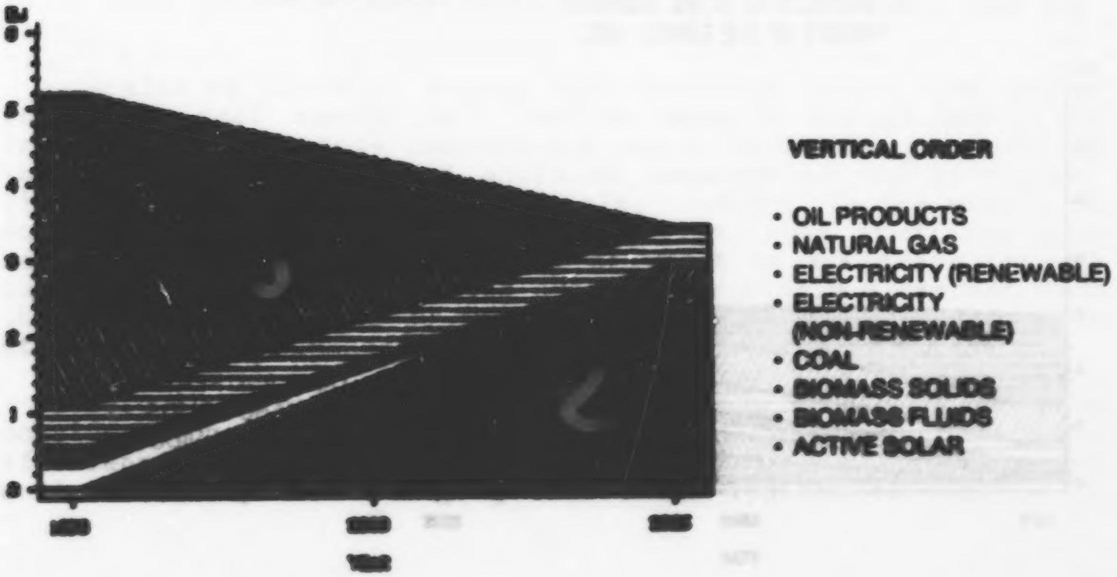
FIGURE 6.5B

ALTERNATIVE ENERGY FUTURES FOR CANADA – PART II

C. CONSUMER SATURATION SCENARIO
FRIENDS OF THE EARTH, 1982



D. CONSERVER SOCIETY SCENARIO
AMORY LOVINS, 1976



particular, Arctic oil and new nuclear power plants were not included, and coal plants and large hydro dams were de-emphasized, in the supply analysis. However, some large-scale nonrenewable energy developments were included, notably oil from Hibernia and from another tar sands or heavy oil plant, natural gas from Sable Island, and electricity from one tidal plant and from those nuclear stations already in use or under construction in 1978 (the base year for the study). Some potential renewable sources of energy, including certain hydroelectric sites and biomass production that might conflict with food production or reduce soil productivity, were also excluded from consideration.

Third, the soft path results cannot be seen as predictive, nor can they define the likelihood of the energy scenarios they develop. Rather, soft path analyses test the feasibility of specific conservation and renewable energy options. Given the assumptions underlying the analysis, the results illustrate efficient energy futures, but whether these futures will in fact occur is a question of policy, not of analysis. That is, the "realism" of the results and scenarios presented here depends largely upon the adoption of the policies and program that finally emerge.

In a sentence, the analysis has shown that economic benefits will accrue to Canada and to each of the provinces primarily from significantly improving the efficiency with which energy is used and secondarily from deriving a larger share of that energy from decentralized, renewable sources -- and it has suggested that significant social and environmental benefits would accrue as well. The conclusions depend mainly on the lower marginal costs of saving energy or of developing it locally relative to investing in additional conventional energy sources. All of the technologies brought into use are already available, and most are already cost-effective. However, the conclusions are policy-sensitive, in that they depend upon economic conditions in which consumers pay full marginal costs for the energy they use and upon institutional conditions in which incentives and barriers are adjusted so that it is no more (or less) difficult to bring new energy sources into use than conventional ones. That is, nothing in the analysis of feasibility implies that the indicated soft path results will come about by themselves. Explicit policy decisions are required, though, as with so much else in this field, as many if not more policy decisions will be required to follow a hard energy path.

6.2 SENSITIVITY OF RESULTS

With the resources available to Friends of the Earth, it was not possible to undertake more than limited sensitivity analysis on a few individual energy options. It is nevertheless of interest to ask how robust are the general results portrayed in this study. While a definitive answer cannot be given, indications are that, in each of its three disaggregated dimensions -- energy, economy and geography -- the results are quite conservative so that reasonable changes in any of the parameters would more likely lead to softer than to harder results.

Changes in the Economy

No direct indication of the sensitivity of the results of this study to changes in the state of the economy can be obtained except by comparison of the two scenarios, and such comparison is hindered by the fact that the Business as Usual scenario incorporated only strictly cost-effective changes whereas the Consumer Saturation scenario allowed some modestly non-cost-effective ones. However, to the extent that an extensive investigation of energy policy in Sweden can be taken as indicative (Johansson *et al*, 1982), there are a number of statements that can be made. First, the single greatest determinant of energy use remains the level of material consumption in society (for any given level of technology). More precisely, given the state of level of technology applied (not just available), there is some positive relationship between the level of the economy and its energy consumption. Ignoring their lack of full comparability, comparison of the different economic and energy growth rates in the two scenarios in this study suggests that each increase (decrease) in economic growth of 0.1% per year leads to an increase (decrease) in energy use, everything else being equal, of 100 to 200 PJ per year in Canada. This result is particularly important because this study was constrained to use a pre-existing projection of the Canadian economy that incorporated improbably high economic growth (4.3% per year between 1978 and 2000).

The relationship between economic growth and energy use can, however, be altered by changes in the composition of output. In Sweden, increases in the share of trade in the economy (implying greater imports and greater exports) made little difference because the energy embodied in imports and exports was largely the same. (Such calculations put direct trade in energy itself to one side.) Indications are that this result would not hold for Canada because our exports tend to be about 25% more energy intensive per dollar of value than our imports (Hamilton, 1977). Hence, any increase in the share of international trade in the Canadian economy would, if we continue to import and export the same sorts of commodities, increase energy use disproportionately. On the other hand, given the high proportion of pulp and paper products in our exports and the huge gains in energy efficiency expected in that industry, the adverse effect on energy use of any general increase in the trade should diminish with time. Similarly, if the composition of Canadian trade shifted such that a greater proportion of our exports came from manufacturing rather than the primary industries, the effect on energy consumption would be reduced. In the Swedish case, swings of as much as 18% in total energy use could be effected depending upon the extent to which any increase in exports between now and 2000 was made up of primary products or of manufactured products. Energy use was almost equally variable depending upon the composition of domestic consumption. For example, if any increase in household expenditures to the year 2000 was shifted from the six most energy-intensive commodities purchased to the six least energy-intensive, and vice-versa, swings of up to 16% in total energy use (respectively 8% above and 8% below the base case) could be effected. While there is no easy way to determine how comparable the numerical results might be, neither is there any reason to question that the direction of these results would be the same in Canada.

Canada: A Special Case or Not

In testing sensitivity more broadly, the question arises as to whether Canada may be a very special case, blessed with abundant resources and low population, so that even if soft path results are feasible here, the results are without relevance for other regions or other nations. Certainly there are limits to the extent to which specific soft path technologies can be transferred from one area to another, but the concept is transferrable, as indicated by the range of countries for which studies have already been done (see Table 1.1B).

More importantly, the argument that soft paths are easy in Canada is at best only a half-truth. It is true that Canada has a low population and that it has a relative abundance of actual and potential energy resources. It is also true that, being so energy inefficient as we were in 1978, dramatic reductions in end-use energy are readily attainable. However, it is also necessary to consider several other factors: First, the population may be small but it is dispersed over a huge area. The distances over which people and goods must be transported are large, and portable fuels for transportation the hardest to find. Second, while much can be done to reduce energy use for heating, the fact is that northern geography still creates special requirements. (For example, electrical requirements must include block heaters for automobiles.) Moreover, if Canada is blessed with large supplies of nonrenewable oil and gas, the climate restricts growth rates for biomass, which is the main renewable alternative. Third, Canadian industry is concentrated in the energy-intensive primary processing sectors. Compared with industry in almost any other country, Canadian industry will continue to use more energy per unit of output so long as our main products (and exports) include pulp, paper, metals and petrochemicals.

In summary, it is as easy to make a case for soft paths being more difficult in Canada as for them being less so. The important point is that soft paths are feasible in Canada, as in every other country where they have been analyzed. Each country has unique problems and must develop unique ways of dealing with them, but there is a huge base of information and an approach that can be shared among them.

Changes in Basic Assumptions

As emphasized above, a major effort was made throughout the study to be conservative in method and assumptions. Indeed, where there was freedom to do so, the approach was biased against soft energy options (Appendix 2.2). The deliberate introduction of "conservatisms," which is common in soft path studies, is clearly intended to make the final results that much more persuasive. However, is it possible that the study also incorporates "optimisms," such that the results are biased in favour of soft paths? The answer is clearly "no" so far as technologies go: given the rate of technical advance and the cost reductions that are evident in the field of energy conservation and renewable sources, arguing against the efficiency figures used in this study is tantamount to suggesting that such progress will cease and even be reversed in the coming decades. On the other hand, re-evaluation reveals three critical aspects -- one each in the field of economics, social/environmental effects and politics -- that do represent optimisms.

The economic optimism involves the price forecasts for conventional forms of energy. It can be argued that, assuming no major disruptions of the world's energy economy, the escalation of real marginal costs assumed in this study (Table 2.4) is too fast. To the extent that marginal costs (hence prices; see comment on politics below) for conventional forms of energy do not rise by as much as projected in this study, conservation and renewable sources will be less cost-effective than indicated. Certainly, expectations of rapidly increasing oil prices have diminished substantially since the study began, but it must be remembered that only the figures for 2000 and 2025 are relevant for our results, and in this context the current glut of oil is of little moment. International resources of low-cost oil are distinctly limited, and many of them occur in politically unstable areas. The argument that our price escalation is too fast carries more weight for natural gas. Up to now, the price of this resource has been tied by government policy to that for oil. However, given the greater resources of natural gas and their wider geographic distribution, price escalation for this fuel could well be significantly slower than has been assumed, even over the long term. As for electricity, indications are that the prices used in this study are, if anything, more likely to understate than to overstate marginal costs.

The social/environmental optimism is more straightforward, yet at the same time less arguable. A number of the soft energy techniques adopted as cost-effective in this study have never been implemented on a large scale, and it is always possible that one or another of them will incur unforeseen social or environmental costs. For example, concern for indoor pollution has been raised with the construction of very tight, energy-efficient buildings. While this fear turns out to be misplaced (the objective in energy-efficient design is not less ventilation but more controlled ventilation), the concern itself was legitimate. The results in this study depend heavily upon the harvesting and burning of biomass, something that, as has been emphasized above, carries with it significant land-use changes and possible environmental dangers. Although a number of studies have indicated that external costs from use of soft energy options are low -- certainly lower than with hard path options -- it would be naive to assume that all such costs have been identified, and, to the extent that they have not, soft techniques may be less acceptable that they now appear.

The last of the three significant optimisms is political, and it is the most important of all. At every stage of this study, it has been assumed that political choices will, over the longer term, be rational and democratic. In particular, the determination of cost-effectiveness is based not on today's subsidized energy prices in Canada but on comparisons of real marginal costs. Anyone who has been involved in the energy debate in Canada knows that this can only be termed a heroic assumption. Volumes of testimony and of parliamentary debate have been devoted to arguments as to why marginal costs should not apply. (Less than three years ago, the Ontario Energy Board went so far as to say that, "the validity of economic efficiency...as the theoretical support for marginal-cost pricing, is rejected by the Board as not being a measurable, achievable or valid goal for Ontario Hydro". (Ontario Energy Board, 1979, p. viii.)) Going beyond pricing and costing, even in the most rational of worlds the implementation of soft energy paths would require more than simply economic rationality. Appropriate building codes and urban plans (plus the elimination of inappropriate ones) must be accepted, as must better integration of local electrical generating opportunities with the grid, and the development of vehicles using alternative fuels together with facilities to service them. There is no good reason to assume that all such adjustments will come about at the times and to the extent appropriate for the implementation of soft energy technologies.

In short, the overall potential for soft energy path futures for Canada turns out in almost every case not to be limited by technological nor even economic factors. Instead, the extent of that potential is policy-determined in the sense that the potential will essentially be determined by political decisions, made primarily by the federal and provincial governments. Put another way, the results of this study indicate that a soft energy path is feasible and likely attractive for Canada, but whether such a path will be chosen is primarily a question of policy not of analysis.

Thus, despite the attempt to adopt conservatisms in this study, some optimisms also play a role. However, the conservatisms and the optimisms are of rather different types. Whereas the former apply to the workings of the model and to the working out of specific supply and demand relationships, the latter apply to the framework within which society is going to operate, and in this sense they can be found in any energy study, hard no less than soft. The reader may judge those optimisms to be of major proportions, and argue that they could significantly delay the introduction of soft energy paths. If someone does so, he or she sould remember that another reader may argue that the framework optimisms of conventional studies are even greater, and conclude that soft paths will be implemented more rapidly than we have suggested. Ultimately, this study is not tied to a particular time frame so much as it is to a particular set of conditions, and it is those conditions that determine the feasibility of soft energy paths.

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APPENDIX 2.1

OUTLINE OF METHOD FOR PROVINCIAL AND TERRITORIAL ANALYSES

The following steps outline the method of analysis used by each provincial/territorial analyst to prepare the soft energy path study in the context of the national model and assumptions described in Chapter 2.

1. Take Statistics Canada Long Term Simulation Model (LTSM), provincial projections of economic output and of population, and disaggregate activity variables by subsector.

   Residential: number of households by housing type (single detached, attached, apartment, mobile).

   Commercial: floorspace by subsector (offices, schools and universities, hospitals, stores and shopping centres, hotels and motels, restaurants, government, street lighting, unallocated; all non-disaggregated consumption to go as unallocated).

   Industrial: output of LTSM industries (agriculture; forestry; fishing, hunting & trapping: iron mines; mineral fuels; other mining; food processing; pulp & paper; iron & steel; smelting & refining; cement; petroleum refining; chemicals; other manufacturing; construction; and electric power, gas & other utilities).

   Transportation: determine modal activity variables for 1978 from relevant Statistics Canada publications (52-210 rail, 53-218 and 53-219 for cars, 53-222 for trucks and 53-215 for bus and urban transit, 54-002 for marine and 51-001 for air) and project activity according to activity ratio for that mode derived from the LTSM modal outputs.

2. Develop costs to be used in demand and supply scenarios, based, where possible upon an amortization or payback period calculation using consistent economic parameters, including a real discount rate of 7 percent. All calculations are to be in constant 1980 dollars.

3. Build energy demand characteristics and demand management measures into end-point economy in 2000 and 2025.

   a) Business as Usual Scenario:
      (i) choose and apply those demand management measures that meet the economic criterion (i.e. cheaper than conventional fuels);
      (ii) if possible, estimate any feedback effects.

   b) Consumer Saturation Scenario:

as above, except that the economic criterion may be relaxed at the discretion of each provincial analyst (such relaxation to be specified clearly in the text).

4. Develop sectoral end-use breakdown by Quality (Heating and Cooling, Process Heat, Fluid Fuel, and Electricity Specific) based on the results of the demand analysis (Step 3).

5. Specify required demand policy measures and impacts in 2000 and 2025.

   a) determine policy measures required during each specified time period;
   b) outline possible implementation measures.

6. Develop an inventory of renewable and nonrenewable energy supplies and their availability at different costs over time. Additional nuclear electricity and frontier oil are excluded by definition from the analysis and other potential supplies may be excluded at the analyst's option provided reasons are given. The supply of conventional fuels is assumed to be infinite in any year at the specified reference costs.

7. Analyze energy supply in 2000 and 2025.

   a) Business as Usual Scenario:
      (i) determine contribution of renewable energy during each time period by matching available renewable fuels to end-use Quality needs. The speed of development of renewable supplies will depend upon the cost of renewables relative to conventional fuels. Once the crossover point is reached (if it is), the renewable contribution will be a function of the penetration rate;
      (ii) determine the supply gaps during each time period to be filled with transitional technologies and/or conventional fuels;
      (iii) determine interprovincial surpluses or deficits. These will be resolved at the national level after the provincial analyses have been carried out, which may require some further iteration of earlier steps at the provincial level;
      (iv) estimate energy requirements of the energy supply industry and add to the demand profiles;
      (v) provide a breakdown of energy supply sources used in 2000 and 2025.

   b) Consumer Saturation Scenario:
      as above, except that the economic criterion determining the crossover point may be relaxed, and the penetration rate speeded up, at the discretion of each provincial analyst (such change to be clearly specified in the text).

8. Specify required supply policy measures in 2000 and 2025:

    a) determine policy measures required for the development of renewable and other supplies;
    b) outline possible implementation measures.

9. Identify potential economic, environmental and social impacts and problems likely to result from the scenarios.

10. Go to steps necessary for national integration (as specified in Chapter 2).

APPENDIX 2.2

MAJOR CONSERVATISMS IN THE SOFT ENERGY PATH STUDY

This appendix outlines the major assumptions made in the study that tended to bias the results against soft energy paths (i.e. conservatisms). These assumptions were of two types: those dictated by the structure of the model used, or by data or resource limitations, and those deliberately introduced in order to increase the robustness of the results.

1. No major changes in values or lifestyles are assumed.

Despite the long time horizon, and large energy price increases in the study, no major changes in lifestyle are assumed. People continue to do the same kinds of things in the same sorts of ways. In the Business As Usual scenario the same patterns of consumer expenditure as those in effect today are assumed to continue. Even in the Consumer Saturation Scenario, where people are assumed to take a greater proportion of their income on leisure, the marginal dollar is spent in exactly the same ways as in the Business as Usual scenario, and in any event the substantial overall increase in per capita income means that individual levels of material welfare still increase.

2. No significant technological changes are assumed.

Despite the rapid pace of technological development in today's society, the economic projections, based on the technical coefficients of Statistics Canada's Long-Term Simulation Model (LTSM), assume no major change in technology as it effects relative inputs and prices. These projections do not, therefore, assume either improvements in processing techniques or changes in the structure of industry. To choose but a few possible examples, new chemical processes for distilling and metallurgical processes for refining offer huge energy savings, as would the substitution of telecommunications for physical transportation.

3. No improvements in the efficiency of materials use are included.

A particularly important technological conservatism involves lack of any changes in the use of metals and materials. Such materials embody a lot of energy at the primary stages of production in which Canadian industry is concentrated, yet this study did not allow for any explicit improvements in materials efficiency (e.g., high-strength steel and concrete) in recycling or in product durability, all of which have significant potential for reducing the usage of primary metals and materials and thus effecting large energy savings.

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4. Market-determined interest rates are assumed to reflect meaningful resource discount rates.

The social value of depletable resources is the subject of controversy within the economics literature. While strong arguments can be made that social time preference rates lower than market-determined discount rates should be used in evaluating public investments in exhaustible resources, we have used a real discount rate of 7% throughout.

5. The social and environmental costs of all fuels have been ignored.

Although it is clear that the social and environmental costs of conservation and most renewable energy sources are lower than those of most conventional sources, no attempt has been made to calculate and include these costs for either set of fuels. The inclusion of such costs would in most cases favour the development and implementation of soft energy technologies over hard ones.

6. Only modest reductions in the real costs of soft energy technologies are assumed.

Although strong evidence exists to indicate that the costs of soft technologies in almost all energy end-use applications and in many energy supply applications will decline in real terms over the next several decades (as a joint result of learning curves in production and installation and of longer production runs), only modest reductions were assumed in this study. In the case of most end-uses, such as passive solar and superinsulation, and of such sources as wood for combustion, no declines at all were included. For solar photovoltaics it was assumed that the goals of the United States Department of Energy (50 ¢ U.S. per peak watt by 1986) would be realized. For both active solar hot water systems and wind electric systems, it was assumed that costs would fall to about half current levels by the turn of the century, which is in line with forecasts in the Technical Reports prepared for the United Nations Conference on New and Renewable Sources of Energy in the summer of 1981. For methanol production from wood feedstocks, an overall reduction of 40% was assumed, which is less than commonly forecast but conditioned by concerns for feedstock supply within Canada.

7. No transportation modal shifts or substitution effects and few load factor improvements were included in the analysis.

Because of the nature of the LTSM projections, which showed large increases in expenditures for all forms of transportation, it was not possible to include shifts between transportation modes in our analysis without violating the consistency of the model. This means that individual modal activity variables (for example, total activity in the air transport sector) for all non-automobile modes were fixed and could not be reallocated to other more efficient transportation modes. In addition, no load factor improvements in cars, trucks, buses or trains were assumed, nor was any substitution of telecommunications for transportation included.

Taken together, these conservatisms mean that the energy demands in the transportation sector that result from our analysis are significantly higher than would otherwise be the case and likely represent maxima, given the economic scenarios projected. Since the Transportation sector requires the use of Liquid Fuel, which is the most difficult quality of energy to meet from soft sources, yet a particularly critical one given the geography of Canada, this means that the analysis probably overstates significantly the difficulties of achieving soft energy paths in this country.

8. Potential savings from cogeneration or energy cascading in industry are not analyzed.

Because of the way in which the industrial demand analysis was undertaken (see Chapter 2), it was not possible to include cogeneration or other forms of energy cascading explicitly in the analysis. That is, the Industrial Task Force goals used in our study were assumed to include a certain amount of cogeneration and cascading but since, for reasons discussed in Chapter 2, it was impossible to know how much was included, it was not possible to add any more. The modest Task Force goals in certain industrial subsectors, and the lack of detailed conservation analysis underlying the development of the Task Force goals, suggest that the amounts of cogeneration and cascading embodied in our results may significantly understate their true potential.

9. Population projection is high.

The population projection incorporated in both LTSM scenarios (Business as Usual and Consumer Saturation) is 0.97% per year to 2025, which is at the extreme high end of Statistics

Canada's range of population projections for the same period. Such growth rates are only achieved by assuming that the fertility rate increases from its current rate of 1.76 children per woman to 2.1 and that net international migration almost doubles to 100 000 per year. The low end of the range of Statistics Canada projections is 0.48% per year with middle projections at 0.6 to 0.8% per year.

10. Solar pre-heating of industrial process heat requirements is excluded.

Because the process heat categories used in this analysis are total and not marginal, solar pre-heating of, say, water ultimately used to produce steam at high temperatures is precluded. That is, some proportion of the energy required to produce process heat at high temperatures could be supplied with low-temperature heat sources, such as solar, after which higher quality energy sources could raise temperatures to the final required temperature. The process heat categories used in our analysis, however, did not separate out pre-heating potential but showed only the total energy required to reach the temperature of the category in question. Since the penetration of solar energy into industry is likely to occur, at least initially, mainly for pre-heating, this potential contribution was precluded.

11. Potential savings from district heating or changes in urban form are not analyzed.

Because of time and resource constraints, and the unknown impact of such changes on LTSM inputs and outputs, no attempt was made to estimate or include energy savings that might result from implementation of district heating schemes or urban planning policies intended to reduce energy use. Since substantial opportunities exist to increase the efficiencies of urban systems in addition to the increases in efficiency of individual buildings that were assumed, in this analysis, the results for urban energy use are significantly conservative.

12. Conservation savings in the energy supply sector were largely ignored.

No conservation savings whatsoever were assumed in the energy supply sector for conventional fuels. In biomass production and conversion, the only saving assumed was an increase in the efficiency of methanol production from wood from 60% for the first plants to 65% by the year 2025. For electricity from wind and the sun and solar hot water heating, modest conservation effects are embedded in the price reductions assumed.

APPENDIX 2.3

SPECIAL STUDIES UNDERTAKEN FOR THE SOFT ENERGY PATH STUDY

The following studies, which for the most part represent reviews of the available literature, were prepared to assist in the analysis of soft path opportunities for Canada. They represent areas where it was deemed more efficient to focus on problems common to the implementation of soft energy paths across Canada (or at least across a number of provinces) rather than on those unique to one province or territory. The studies are each given a brief title to indicate subject matter; in each case the full title would more appropriately be "The Potential Role of X in a Soft Energy Path for Canada".

Agriculture - Herman Boerma, Saskatchewan Environmental Society, Saskatoon, SK.

Air Transportation - James O'Reilly, Energy Probe, Ottawa, ON

Aluminum Production - Vivian Neale, Energy Probe, Ottawa, ON

Appliance Use - William Ross, Faculty of Environmental Design, University of Calgary, Calgary, AB

Industrial Process Heat - Jay Lewis, SPEC, Vancouver, BC

Marine Transportation - Geoff Stiles, Island Energy Consultants St. John's, NF

Methanol Production - Auguste Gallant, Senopi Consultants, Ltd., Petit Rocher, NB

Peaking Problems for Utilities - Jack Gibbons, Energy Probe, Toronto, ON

Photovoltaics - Susan Holtz, Ecology Action Centre, Halifax, NS

Railroad Transportation - James O'Reilly, Energy Probe, Ottawa, ON

Shared-Ride Taxis and Other Para-Transit - Margaret Oldfield, Energy Probe, Ottawa, ON

Solar Space and Water Heating - William Ross, Faculty of Environmental Design, University of Calgary, Calgary, AB

Urban Form and Energy Use - Margaret Oldfield, Energy Probe, Ottawa, ON

Wind Energy - Kirk Brown, Institute of Man & Resources, Charlottetown, PE

APPENDIX 2.4

RECONCILIATION OF SECTORS IN LTSM, STATISTICS CANADA CATALOGUE 57-003, AND INDUSTRY TASK FORCE CATEGORIES

The following table and notes shows how reconciliation was affected, for the purpose of the Soft Energy Path study, among the energy use categories of: (1) Statistics Canada's _Quarterly Report on Energy Supply-Demand in Canada_ (Catalogue 57-003), (2) the industry categories of Statistics Canada's Long-Term Simulation Model (LTSM) and (3) the industry categories of the Canadian Industry Energy Conservation Task Forces.

RECONCILIATION OF LTEM, 57-003 AND INDUSTRY TASK FORCE CATEGORIES

57-003 Categories		LTEM Categories		Task Force Categories[3]
Name	**Line Number[1]**	**Line Number[2]**	**Name**	
Agriculture[4]	37	1	Agriculture	-
Forestry	27	2	Forestry	part of "Pulp and Paper"
-[5]	-	3	Fishing, Hunting & Trapping	-
Iron Mines	17	4	Iron Mines	part of "Mining and Metallurgy"
part of Producer Consumption[6]	part of 14	5	Mineral Fuels	use "Mining and Metallurgy"
Total Mining minus Iron Mines	18 minus 17	6	Other Mining	"Mining & Metallurgy" & "Industrial Minerals"
part of Other Manufacturing[7]	part of 25	7	Food Processing	"Food and Beverage"
Pulp and Paper	19	8	Pulp and Paper	"Pulp and Paper"
Iron and Steel	20	9	Iron and Steel	"Ferrous Metals"
Smelting and Refining	21	10	Smelting and Refining	part of "Mining and Metallurgy"
Cement	22	11	Cement	"Cement"
Petroleum Refining plus part of Producer Consumption[8]	23 plus part of 14	12	Petroleum Refining	"Petroleum Refining"
Chemicals	24	13	Chemicals	"Chemicals"
Other Mfg. minus food processing[7]	25 minus food processing	14	Other Manufacturing	"Total"
Construction	28	15	Construction	-
Canadian Airlines[9]	31	16	Air Transport	-
Marine minus fishing	33 minus fishing	17	Water Transport	-
Railways	32	18	Rail Transport	-
Road Transport and Urban Transit and Retail Pump Sales[10]	35 & 36	19	Truck Transport	-
		20	Bus (Inter-Urban)	-
		21	Urban Transit	-
Pipelines	34	22	Pipeline Transport	-
General[11]	-	23	Elec. Power, Gas & Other Utilities	-
Other Commercial/Institutional[12]	40	24	Commercial and Other	-

Notes:
1. from Table 1B, 57-003
2. from LTEM
3. from Table 2.6
4. Agriculture in 57-003 includes farm housing
5. put energy consumption at zero or do province-specific analysis - see attached notes (#2)
6. primary Producer Consumption net of primary electricity; see attached notes (#3)
7. to be allocated by PRT's for their province, see attached notes (#4)
8. see attached notes (#5)
9. see attached notes (#6)
10. The Secretariat will provide PRT's with a breakdown, see attached notes (#7)
11. see attached notes (#8)
12. for line 39 of 57-003 (Public Admin.), see attached notes (#9)

Notes to Provincial/Territorial Analysts Regarding Reconciliation of LTSM and Stats Can 57-003 Numbers

1. **Re LTSM line 3 - Fishing, Hunting and Trapping.** Since this category does not appear in 57-003, those provinces with significant amounts of these activities (eg. Maritimes) may want to develop energy use numbers locally. Equivalent amounts should then be subtracted from other 57-003 lines (eg. from line 33 - Marine).

2. **Re LTSM line 5 - Mineral Fuels.** This industry is part of the energy supply industry. It consists of coal mines and the oil and gas industry. As such it will be treated in the supply analysis. The energy use of this industry shows up in 57-003 as primary fuel consumption, not including electricity (ie. coal, crude oil, natural gas, gas plant LPG's) in line 14 - Producer Consumption. From this must be subtracted the gas used by gas utilities (line 23 of LTSM). See note 8. (N.B. In 57-003, Producer Consumption shows the producing industries' consumption of only their own roducts; thus the coal use shown in line 14 is only that coal used by coal mines, etc.)

3. **Re LTSM line 7 - Food Processing and line 14 - Other Manufacturing.** Since 75-003 does not separate out the food processing industry, its consumption is buried in line 25 of 57-003 - Other Manufacturing. Therefore, each analyst must separate it out for her/his province and assign it to line 7 of LTSM. When you do so, be sure to subtract it from Other Manufacturing in 57-003. In other words Other Manufacturing in LTSM is equal to Other Manufacturing in 57-003 minus food processing.

4. **Re LTSM line 12 - Petroleum Refining.** This is equivalent to line 23 of 57-003 (Petroleum Refining) plus that part of producer consumption (line 14 of 57-003) consumed by the Petroleum Refining industry. Since, as indicated in note 3, the producer consumption line of 57-003 shows only the producers' consumption of their own products, the consumption shown in line 14 of 57-003 in the column titled "Refined Petroleum Products" is all consumed by the Petroleum Refining industry. This consumption should then be added to the consumption shown in line 23 of 57-003 to get total consumption of the Petroleum Refining Industry.

5. **Re LTSM line 16 - Air Transport.** 57-003 has two entries for air transport: line 31 - Canadian Airlines and line 32 - Foreign Airlines. Only the former is covered by line 16 of LTSM. This means that you

can ignore Foreign Airlines consumption in your analysis. (In principle, it should be treated like a fuel export.)

6. Re LTSM lines 19 - Truck Transport, 20 - Bus (Inter Urban) and 21 - Urban Transit. The 57-003 road transport categories are broken down differently than in LTSM. This means that you will have to use the following StatsCan publications to derive road transport consumption numbers: 53-215 (Passenger Bus and Urban Transit Statistics), 53-218 (Road Motor Vehicles - Fuel Sales), and 53-222 (Motor Carriers - Freight and Household Goods Movers). Unfortunately, the categories in these reports do not correspond precisely to LTSM categories either but an allocation can be made as follows: (i) allocate all the bus fuel use from 53-215 to inter-city buses; (ii) allocate all the fuel use from 53-222 to trucks; (iii) determine how much of the national transit fuel use figures shown in 53-215 apply to your province (N.B. the national total is less than 0.1% of gasoline and diesel use in the road subsectors); (iv) allocate the fuel use in 53-218 between trucks and cars (most of it will be for the latter).

7. Re LTSM line 23 - Electric Power, Gas and Other Utilities. The electric utilities part is easy - it is simply the electricity consumption shown in line 14 of 57-003 (Producer Consumption). To this should be added the energy consumption of gas and 'other' utilities. The other utilities are also easy: ignore them. The gas utilities energy consumption is a problem. It is part of the gas consumption shown in line 14 of 57-003 but cannot be derived from 57-003. The best bet for this is another StatsCan publication, 57-205 (Gas Utilities). Line 36 of Table 6 of that publication is approximately what we want. The amounts shown there should be subtracted from gas consumption in line 14 of 57-003 (see note 3). The energy consumption of the electric utilities should be added to that of the gas utilities to get total energy consumption for line 23 of LTSM. The sum of this consumption and that shown for line 5 of LTSM (Mineral Fuels) should total to the "Total Primary Sources" column of line 14 of 57-003. Please make this calculation as a check on your numbers.

8. Re LTSM line 24 - Commercial and Other.
Since LTSM treats the government sector (and the household sector) as a final demand sector, no figures for government output are given in LTSM. Thus line 24 of LTSM corresponds only to line 40 of 57-003 - Other Commercial/Institutional. For growth of activity in the government sector, you should assume that the government retains the same relative share of final demand that it had in 1978 and therefore that it grows at the same rate as total Canadian output.

APPENDIX 2.5

A COMPARATIVE ANALYSIS OF ETHANOL AND METHANOL PRODUCTION FROM WOOD PLANTATIONS IN CANADA

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May, 1982

This appendix outlines a preliminary comparison of methanol and of ethanol in terms of their relative energy yield from the same wood feedstock. An estimate of potential wood productivity on unimproved and abandoned farmland in Canada is made and this wood is assumed to be used either for the production of ethanol, through acid hydrolysis, or the production of methanol, through wood gasification.

Tree Species

Studies in the U.S.[1,2] have indicated that high growth hybrid poplar and red alders could produce 25-54 metric tonnes/ ha.yr. with 6 year rotations, provided they were intensively managed and had sufficient irrigation and fertilization. In British Columbia, the red alder was found capable of producing 18 t/ha. yr. under managed conditions for rotation age of 10 years or less.[3]

Productivities of 14 oven dried tonnes (ODT) per hectare per year and 8 year rotations will be used in this analysis.

Land availability

According to the Canada Land Inventory, 3.4% of the total land area in Canada is either unimproved land considered potentially arable or abandoned farmlands.[4] Table 1 summarizes this regional availability.

Ethanol -- Acid hydrolysis of wood

Using mineral acids, lignocellulosic materials such as wood can be hyrolyzed to produce fermentable 6-carbon sugars. For poplar and alders the percent of potential hexoses is about 50%.[5] After yeast fermentation and distillation, ethanol is obtained.

This process, which has been used in the Soviet Union in 45 factories, has been the object of some interest in Brazil. An analysis of its feasibility, including a detailed energy balance and a comparison with ethanol production from sugar cane has been prepared.[6] The yields of hydrolysis, fermentation and distillation are 70%, 97%, and 97% respectively. The ethanol productivity is 216 L/ODT of wood hydrolysed.

The heat necessary for hyrolysis, fermentation and distillation can be obtained by burning some of the wood and the lignine, a by-product of hyrdolysis (ca. 30% of dry wood is lignin). To process one oven dried metric tonne of wood, 3200 kg. of steam (or 1.73×10^6 Kcal = 7.23 GJ) are necessary. We will consider the furnace efficiency to be 65% and the heat of combustion of dry wood to be 4100 Kcal/Kg. or 17140 KJ/Kg.

For each metric tonne of wood hydrolysed, the burning of the resulting lignin gives 0.80 x 10^6 Kcal (or 3.34 GJ). (6) The remainder of the required heat (1.73 x 10^6 - 0.80 x 10^6 Kcal or 3.89 GJ) can be obtained by burning 0.33 tonnes of wood. Then, 216 L of ethanol are produced from 1.33 tonnes of wood (162.4 L/t) and the ethanol production is 2274 L/ha.yr. (or 11.5 x 10^6 Kcal/ha.yr. or 48.1 GJ/ha.yr.).

Table 2 shows the production characteristics of ethanol production from wood hyrolysis derived from reference 6.

Methanol -- Wood gasification

The conditions used for this report are based on methanol production from wood gasification, according to reference 7. A high pressure system for methanol production is powered by installed electric power, generated by thermo electric units, which consume 147,550 Kg/h of steam at an input pressure of 60 atm and output of 2 atm, for a factory operating continuously 330 days a year and producing 1.89 x 10^8 L/yr.

The methanol production is 1 tonne per 2.24 ODT of wood, or 446 Kg of methanol/ODT wood. The methanol density is 0.79 g/cm^3. Therefore, the methanol productivity from gasified wood is 565 L/tonne.

If this factory produces 1.89 x 10^8 L/yr, or 2.386 x 10^4 L/hr, then 42.24 tonnes of wood are gasified per hour.

A large fraction of the combustible material used in the boiler (56%) consists of heavy hyrocarbons produced during the gasification process and the balance (44%) is wood that is burnt at the rate of 15.8 ODT/hr. Therefore, to process 42.24 tonnes of wood (to get methanol), 15.8 ODT are burnt or 0.37 ODT of wood per tonne of methanol processed. Given the preliminary nature of this analysis, this can be considered equivalent to the figure derived above for the wood required to fuel the ethanol production process. In other words both processes have similar external energy requirements per ton of alcohol produced. The net methanol productivity is, then, 412.4 L/ODT or 5774 L/ha.yr. (or 21.9 x 10^6 Kcal/ha.yr. or 91.6 GJ/ha.yr.).

Energy from wood plantations in Canada

Considering, as is shown in Table 1, that almost 31 x 10^6 hectares are available for wood plantations in Canada, it is possible to estimate the amount of ethanol and methanol that can be obtained annually from wood hydrolysis and gasification, respectively. Taking wood productivity to be 14 t/ha.yr. and 8 year rotations, Table 3 shows for each region the amount of wood that could be obtained if all this land were utilized for biomass planations. Given this wood productivity figures, Table 4 shows the amount of ethanol that can be produced and Table 5 the amount of methanol that can be produced.

As the heat of combustion of ethanol is 5056 Kcal/L (or 21154 KJ/L)[7], the total potential arable unimproved land could produce 3.5 X 10^{14} Kcal/yr. (or 1.5 x 10^{18} J/yr.). As the heat of combustion of methanol is 3792 Kcal/l (or 15866 KJ/l),[8] the total potential arable unimproved land could produce 6.8 x 10^{14} Kcal/yr (or 2.8 x 10^{18} J/yr).

The results of this broad preliminary analysis suggest that almost twice as much energy can be produced, from the same wood feedstock, in the form of methanol as in the form of ethanol. Using hybrid poplar plantations, on an 8 year rotation, in abandoned and unimproved farmland in Canada, about 8.6 EJ of methanol, or 4.4 EJ of ethanol could be produced on a sustained yield basis.

Table 1: Area available for growing energy crops.[4]

	Potential arable unimproved land (10^3 ha.)	Abandoned farmland (10^3 ha.)	Total (10^3 ha.)
Newfoundland	258	139	397
Prince Edward Island	258	139	397
Nova Scotia	1426	747	2173
New Brunswick	3176	863	4039
Quebec	2552	2424	4976
Ontario	5580	1991	7571
Manitoba	2344	--	2344
Saskatchewan	1180	--	1180
Alberta	8236	--	8236
British Columbia	--	--	--
TOTAL	24752	6164	30916

Table 2: Production characteristics of ethanol[6] and methanol[7] production from wood.

	Acid Hydrolysis (Ethanol)	Gasification (Methanol)
Productivity (L/ODt of wood processed)	216	565
Wood Burnt to produce energy (ODt/ODt of wood processed)	0.33	0.37
Net alcohol productivity (L/ODt consumed)	162	425
Heat of combustion (KJ/L)	21,154	15,866

Table 3: Wood Available for Methanol or Ethanol Production

	Area Available (10^3 ha.)	Land Ready for Harvest (ha./day)	Wood Obtained (10^3 oven dried tonnes/day)
Newfoundland	---	---	---
Prince Edward Island	397	150	16.8
Nova Scotia	2173	823	92.2
New Brunswick	4039	1530	171.3
Quebec	4976	1885	211.1
Ontario	7571	2868	321.2
Manitoba	2344	888	99.4
Saskatchewan	1180	447	50.1
Alberta	8236	3120	349.4
British Columbia	---	---	---
TOTAL	30916	11711	1311.6

Table 4: Potential Ethanol Production in Canada

	Ethanol Productivity (10^6 L/day)	Energy Obtained as Ethanol (TJ/day)
Newfoundland	---	---
Prince Edward Island	2.7	57
Nova Scotia	14.7	312
New Brunswick	27.4	580
Quebec	33.8	714
Ontario	51.4	1087
Manitoba	15.9	337
Saskatchewan	8.0	169
Alberta	55.9	1183
British Columbia	---	---
TOTAL	209.8	4439

Table 5: Potential Methanol Production in Canada

	Methanol Productivity (10^6 L/day)	Energy Obtained as Methanol (TJ/day)
Newfoundland	---	---
Prince Edward Island	6.9	110
Nova Scotia	38.0	603
New Brunswick	70.7	1121
Quebec	87.1	1381
Ontario	132.5	2102
Manitoba	41.0	651
Saskatchewan	20.6	382
Alberta	144.1	2286
British Columbia	---	---
TOTAL	540.9	8582

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APPENDIX 3.1

GENERAL NOTES FOR TABLES AND FIGURES

The highly complex nature of energy supply and demand, subdivided by sources, forms, sectors and qualities, required the development of a number of complex tables and figures to show details on energy production and use in different scenario-years. In particular, the tables tracing energy disposition by source and form from production through to end-use (Tables CA-2, CA-12, CA-13, CA-14, CA-15) and the figures showing energy end-use subdivided by sector and then by form (Figures CA-1, CA-4, CA-5, CA-7, CA-8) are complicated and require some study to be fully understood. As an aid to such understanding this appendix contains a description of those tables and figures. The description should be read in conjunction with the table or figure to which it refers. These same tables and figures, under the same titles, also appear in each of the provincial studies. The corresponding provincial tables are numbered XX-1, XX-12, XX-13, XX-14, and XX-15; the corresponding provincial figures are numbered XX-1, XX-4, XX-5, XX-7 and XX-8 (in both cases XX represents the two letter provincial code).

Also included in this appendix is a description of the energy flow maps (Figures 3.19 through 3.24) that show the major flows of energy within, from and to Canada in 1978 and in the scenarios analyzed in this study.

General Notes for Tables Entitled Production of Primary Sources and Secondary Forms

These five tables are designed to show the use of primary sources of energy as well as the ways in which those sources appear as secondary forms. With a few exceptions to be noted below, primary sources and secondary forms are kept strictly apart and accounts are kept according to whether it is a primary source or secondary form that is being used. Thus, crude oil appears on the left (primary) part of the table and refined petroleum products (RPPs) on the right (secondary) part. Note that, contrary to the common situation, energy use by the Energy Supply sector is nil for the conversion of crude to RPPs. This is because the energy used in this conversion is in fact RPPs; hence, that volume of use is shown on the right in the Energy Supply sector for RPPs. In fact, this cell (RPP row; Energy Supply sector column) contains the total for all use of RPPs in all energy supply industries, including that used to pump oil out of the ground, to operate coal mines and to make methanol from biomass, among other things. In contrast, the coal used to generate electricity is shown in the primary energy supply sector because it is used as coal; it is the electricity that is secondary.

Special problems arose with the use of RPPs (mainly as heavy fuel oil and diesel oil) to general electricity. The problem stems from the two-stage conversion--crude to RPP to electricity--which would ideally require a third section of the table. In order to avoid enlarging the table unduly, the loss of RPPs in their conversion to electricity is shown on the left (primary) side of the table; the RPPs required to produce the RPPs are of course still shown on the right (secondary) side. Natural gas used to generate electricity is treated in exactly the same way.

All electricity is treated in the table as a secondary form of energy and shown in a single line. (Once generated, electricity from one source is indistinguishable from that from any other.) However, all primary sources, whether thermal, nuclear, solar or hydroelectric, are shown separately on the left. This results in double counting in the secondary production column since the production of electricity from each source is shown separately there and is also contained in the Total Electricity line. Hence total electrical production is shown in square brackets. To be consistent, all transmission and distribution losses (together with any electricity used in other energy supply industries) is shown as secondary use (electricity row; Energy Supply sector column.)

In provincial versions of this table, all accounting is shown in the province of use. Thus, natural gas used to extract gas in Alberta and pump it to the provincial border is shown as a secondary use of natural gas in Alberta. (If electricity is used for pumping, such use of course appears in the electricity row.) If the gas is ultimately sold to a consumer in Ontario, that province would account for pumping from the border and for distribution; Saskatchewan and Manitoba would each show the use of gas (or of electricity) to move the gas across the provinces. The same approach is used to account for and allocate transmission and distribution losses for electricity. (A few exceptions occur where electricity is generated close to the border of one province and transmitted to the neighboring province.)

It should be apparent that, as constructed, these tables do not show the losses in the flow of material from primary source to secondary form on a single line. Loses are shown in that part of the table appropriate to the nature of the use. However, taken together the energy supply columns do show the sum of primary extraction or harvesting energy, producer use at all plants, conversion (thermodynamic) losses in going from one kind of energy to another, and transportation, transmission and distribution energy. Unfortunately, data gaps preclude accounting for much of the energy costs of transporting crude oil and RPPs. These energy uses are hidden in other transportation and commercial categories, such as railroads.

General Notes for Figures Entitled Energy End-Uses and Forms

These five figures are pie charts that, for the year and scenario indicated, show at once three breakdowns of energy use: by quality, by sector and by form. Reflecting on demand-oriented perspective on energy policy issues, which is based on the recognition that the fundamental purpose for which energy is used is to meet end-use needs, in these diagrams energy end-uses or qualities are literally central. The key to understanding the figures is that, starting from the centre, the wedges extend outward consistently so that, for example, the wedge denoted HC (for Heating and Cooling; see just below) comprises the share of energy used in this quality, and, as the wedge extends outward to the larger concentric circle, it is subdivided to show the sectors that use Heating and Cooling energy and their relative shares of this energy; finally, bar charts just outside the outer circle show the forms in which each sector uses its share of that heating and cooling energy. Thus, to use Figure CA-5 in the national report as an example, one can get, at a single glance, an idea of what proportion of total secondary energy use in the Business as Usual scenario in 2025 would be used for Heating and Cooling, what proportion of that Heating and Cooling energy was used in, say, the Commercial sector, as well as the forms of energy that the Commercial sector was using to provide for its Heating and Cooling needs.

The three breakdowns can be described in more detail. The centremost circle is broken into the four main subdivisions of energy quality by heavy black lines. In lieu of shading, the four are identified by initials as follows: HC - Heating and Cooling (ie. low temperature energy): PH - Process Heat (ie. industrial heat requirements for process purposes); ES - Electricity Specific (ie. all uses of electricity), excluding space and domestic water heating); and LF - Liquid Fuel (ie. all end-uses, such as internal combustion engines that require energy in a liquid form).

The heavy black lines form wedges that extend outward into a concentric circle that is in turn subdivided by sector of use. These four sectors are denoted (Residential, Commercial, Industrial and Transportation) by shading, as indicated on the figure. In principle, each quality wedge could be subdivided into four sectoral subdivisions if that quality of energy was used in each sector. In practice, things are not that complicated. Heating and Cooling energy, for example, is used in the Residential, Commercial and Industrial sectors, but not in Transportation; on the other hand, Liquid Fuel is used predominantly in the Transportation sector. The chart thus allows the reader to get some idea of what sectors use what qualities of energy.

The pie chart has now been subdivided into smaller wedges representing sectoral use of energy of different qualities. In effect, these smaller wedges are again extended outward and further subdivided according to the form of energy used for the given sectoral quality. However, because such subdivisions become hard to read, bar charts placed just outside the outer circle of wedges, have been used instead. Different styles of cross hatching indicate the form in which the energy is used. Thus each bar represents the relative amount of that form of energy used in the corresponding sector to supply energy of the corresponding quality. Since all the bars are relative to each other, some idea of the total use of a given form of energy, by sector, by quality or in total can also be gathered by mentally adding the sizes of the relevant bars.

These figures present what amounts to a snapshot of secondary energy use in any year. In order that the snapshot be adequate (and useful), the three main dimensions of energy use (quality, sector, form) used in our report have had to be compressed onto two dimensions of a sheet of paper. There is no entirely adequate method of doing this, and admittedly these figures are a bit complex. However, they contain such a large amount of information that we believe the reader will find it worthwhile taking the time to learn how to read them.

General Notes for Figures 3.18 through 3.22 (flow maps)

These five figures show the major flows of energy as determined by Statistics Canada for 1978 and as projected under the two scenarios for 2000 and 2025. Arrows show the direction, and numbers of volume, of energy for the source or form indicated moving between the province (or country) of final consumption. However, 1978 imports are shown according to the port of entry, not the province in which the energy is used, and some 1978 exports may not have been traced accurately to the province of original production. In-transit flows (as when Alberta oil passes through Manitoba on its way to Ontario) are ignored, as are transportation losses. Where energy passes in both directions across a border (as is common with electricity), only net flows are shown.

In order to avoid complicating the diagrams, the three Maritime provinces have been treated as a unit; hence, shipments from Sable Island gas fields, which in our scenarios are used entirely within the Maritimes, do not appear.

All data have been rounded to the nearest 10 petajoules, and flows of less than 5 petajoules have been ignored. Data for 1978 may not accord completely with those in provincial reports because they were compiled in part from different sources.

TERMINOLOGY AND UNITS

In order to meet the analytical requirements of the study, a number of special terms and concepts were used. These terms, and others important to the study, are defined in the attached Glossary. Lists of standard prefixes and of acronyms used in this report are also included.

Throughout, the study is conducted in SI (System International) metric units as outlined in Canadian Standards Association, Canadian Metric Practice Guide (CAN3-Z234.1-79), 1979. The main SI energy units are defined in the Glossary; in addition, conversions between these units and Imperial and natural units are shown in the attached Conversion Factors table, derived from Statistics Canada Quarterly Report on Energy Supply-Demand in Canada, (Catalogue 57-003) and various other publications. Unless otherwise indicated, all values for energy use or production are reported in Petajoules (PJ).

GLOSSARY

N.B. All terms capitalized in the definitions are themselves defined elsewhere in this Glossary.

Active Solar - one of the secondary Form categories used in this report, referring to all heat energy derived directly from the sun by means of mechanical solar collectors.

Backcasting - a non-predictive analytical approach that involves setting specific energy policy goals or targets in the future and then analyzing the feasibility and implications of trying to reach these targets.

Biogas - methane-based gas with a low heating value derived by anaerobic digestion from organic waste products (such as municipal solid waste or manure), and other kinds of Biomass; included in the Biomass Fluids category in this report.

Biomass - one of the primary source categories used in this report, referring to unfossilized organic material used for energy production, including, among other sources, wood, crop waste, municipal solid waste and mill waste.

Biomass Fluids - one of the secondary Form categories used in this report, referring to Biomass used in fluid form, including Biogas, Methanol, Ethanol and Vegetable Oils.

Biomass Solids - one of the secondary Form categories used in this report, referring to Biomass used in solid form, such as roundwood, chips or pellets, and including wastewood products used at pulp and paper mills.

Bottom-Up Analysis - an analytical approach to energy demand analysis that involves starting with actual end-uses or services provided by energy and building energy demand up "from the bottom".

Btu - an energy unit in the Imperial system (not used in this report); equal to 1055 Joules.

CNG - Compressed Natural Gas - Natural gas in metal containers under pressure of 60-100 MPa (10^6 Pascals) to increase its energy density and thus permit usage away from pipeline connections.

Coal and Peat - one of the Primary Source categories used in this study, referring to all types of coal and peat.

Cogeneration - the joint production, from the same fuel, of electricity and of steam used for Process Heat requirements.

Commercial Sector - one of the four Secondary Use sectors used in this study, encompassing the following sub-sectors: offices, schools and universities, hospitals, stores and shopping centres, hotels and motels, restaurants, and government.

Cost Effectiveness - a form of energy is considered cost-effective if its annualized price per gigajoule (at 7% real over 20 years) is less than or equal to the projected price of oil or natural gas.

Crude Oil - one of the primary Source categories used in this report, referring to petroleum in the form in which it enters the refinery.

District Heating - the supply of heat in the form of hot water or steam to a group of buildings from a central source, such as a Cogeneration plant.

Efficiency - the ratio of work done to energy used; i.e. activity or output per unit of energy input (eg. miles per gallon, output per unit input of a furnace); sometimes referred to as "first law efficiency" and equal to the inverse of Intensity.

Electricity Specific - one of the four energy Quality categories used in this study, referring to those end-uses, such as electric lighting, electric motors, electronics, telecommunications, electrometallurgy, etc., that require energy in the form of electricity; in this study it was approximated by total electricity use excluding all space and domestic water heating uses.

Embodied Energy - the energy used as an input in the production of a commodity or service.

End-Use - the actual task or service that energy performs or provides, measured at the Tertiary level, such as heat or motive power.

Energy Supply Sector - those industries that produce secondary energy Forms, including the petroleum and biomass refining industry, the mineral fuels industry, the pipeline industry and the utility industry.

Ethanol - liquid alcohol fuel formed by fermentation of sugars, usually produced from sugar or starch crops or cellulose (wood); included in the Biomass Fluids category in this report.

First Law Efficiency - a measure of energy efficiency based on the first law of thermodynamics (conservation of energy); equivalent to the direct Efficiency of a given energy-using device (eg. a furnace) and calculated by dividing the useful energy (Tertiary) output of that device by the secondary fuel input.

Fluidized Bed Combustion - a process for burning coal or other solid materials in which the fuel is introduced onto a greater volume of hot inert particles maintained in a state of turbulence by a stream of air from below.

Form - the category used in this study to denote secondary energy products or fuels. The energy Forms used in this study are Coal and Peat, Natural Gas, Refined Petroleum Products, Electricity, Biomass Solids, Biomass Fluids, and Active Solar.

GDP - Gross Domestic Product - A statistical estimate of the volume of commercial activity taking place within an economy.

Geothermal Energy - energy derived from naturally-occurring geological reservoirs of heat in the earth's crust.

Heat Pump - a heating or cooling device which transfers heat from a colder to a hotter reservoir (eg. from the ground to a room in a house) by the expenditure of mechanical, electrical or thermal energy.

Heating and Cooling - one of the four energy Quality categories used in this study, encompassing all space heating and cooling and hot water requirements to less than 100 degrees C.

Hydro - one of the primary Source categories used in this report, referring to electricity generated by turbines from falling or moving water and measured in terms of the amount of electric energy generated.

Industrial Sector - one of the four Secondary Use sectors used in this study, encompassing the mining, manufacturing, forestry, fishing, hunting and trapping, and construction industries, and including non-residential use of energy on farms, but excluding the Energy Supply Sector.

Intensity - the ratio of energy used to work done; ie. Secondary energy use (input) divided by some activity variable (eg.

litres per 100 kilometres, fuel use per tonne of product in industry, etc.); equal to the inverse of Efficiency.

Joule - a force of one newton (equivalent to one kilogram accelerated to one metre per second squared) acting through a distance of one metre, equal to .000948 Btu.

Liquid Fuel - one of the four energy Quality categories used in this study, encompassing all energy requirements for which fuel in a liquid form is required, such as automobile transportation.

Liquified Petroleum Gases - petroleum-derived gases such as propane and butane, included in this study under Refined Petroleum Products.

Long-Term Simulation Model - a materials balance model of the Canadian economy developed by Statistics Canada, based on the Canadian input/output tables and used in this study to project a future Canadian economy as a basis for analysis.

Methanol - liquid alcohol fuel formed either synthetically from any carbon source, or from the destructive distillation of wood; included in the Biomass Fluids category in this report.

Natural Gas - one of the primary Source categories and secondary Form categories used in this study.

Non-Energy Use - the use of energy as a feedstock or raw material rather than as a fuel; includes the manufacture of petrochemicals, lubricating oils and greases, ashphalt and other non-energy products, and the production of coke used as a reductant.

Primary Production - the total amount of energy Sources produced, measured at the point of production.

Process Heat - one of the four energy Quality categories used in this study, defined here as encompassing all energy requirements for heat greater than 100 degrees C., including pre-heating.

Quality - the category used in this report to refer to the type of energy needed to meet different end-use needs at the secondary level. The quality categories used in this study are Heating and Cooling, Process Heat, Liquid Fuel and Electricity Specific.

Refined Petroleum Products (RPP's) - secondary Forms produced from crude oil and including LPG's, still gas, gasoline, diesel fuel oil, light fuel oil, heavy fuel oil, petroleum coke, aviation gas, aviation turbo fuel and certain non-energy products.

Residential Sector - one of the four Secondary Use sectors used in this study, encompassing all energy used in homes, including apartments, and mobile homes, plus household energy use on farms.

Second Law Efficiency - a measure of energy Efficiency based on the second law of thermodynamics; equivalent to the overall Efficiency of a given energy-using task and calculated by dividing the theoretical thermodynamic minimum amount of available energy needed to perform that task by the amount of available energy actually used to perform the task.

Secondary Production - the total amount of energy Forms produced for use; equivalent to Primary Production less transformation losses, net exports of Primary Sources and the use of Primary Sources by the Energy Supply Sector.

Secondary Use - the amount of energy Forms used in the Residential, Commercial, Industrial and Transportation sectors; equivalent to Secondary Production less non-energy use, net exports of secondary Forms, and the use of secondary Forms by the Energy Supply Sector.

Soft Energy Paths - energy policy paths based upon conservation, and the use of Soft Energy Technologies.

Soft Energy Technologies - energy supply technologies that are: 1. renewable, 2. diverse, 3. relatively flexible and easy to use; 4. matched in scale and geographic distribution to end-use needs; 5. matched in thermodynamic quality to end-use needs.

Solar - one of the primary Source categories used in this report, referring to all energy derived directly from the sun and converted to heat or electricity plus all geothermal energy production where noted.

Source - the category used in this study to denote primary energy products. The energy Sources used in this study are Coal and Peat, Natural Gas, Crude Oil, Hydro, Solar, Wind and Biomass.

Technical Feasibility - An energy supply or demand technology is considered technically feasible if it was available off-the-shelf or in prototype form in 1982.

Tertiary Use - the amount of energy that actually provides the desired work or service, equal to secondary energy used multiplied by the conversion efficiency of the end-use device.

Thermodynamic Matching - a process whereby energy Forms are matched to End-Uses in terms of the Quality of the energy Form required to meet that end-use need.

Transportation Sector - are of the four Secondary Use sectors used in this study, encompassing all transportation energy use except private transportation fleets not used on highways or as common carriers (which are included with the Industrial Sector).

Vegetable Oils - oil naturally produced by plants, such as rapeseed, milkweed and rubber trees, included in the Biomass Fluids category in this report.

Wind - one of the primary Source categories used in this report, referring to electricity generated from wind machines, and measured in terms of the amount of electric energy generated.

SI Prefixes

k - kilo or 10^3

M - Mega or 10^6

G - Giga or 10^9

T - Tera or 10^{12}

P - Peta or 10^{15}

E - Exa or 10^{18}

Abbreviations Used in Report

AB - Alberta

BC - British Columbia

BU - Business as Usual Scenario

CS - Consumer Saturation Scenario

EJ - Exajoule

ECOSB - Energy Conservation and Oil Substitution Branch, EMR

EMR - Department of Energy, Mines and Resources

ES - Electricity Specific

GJ - Gigajoule

H&C - Heating and Cooling

kW.h - Kilowatt-hour

L - Litres

LF - Liquid Fuel

LPG - Liquified Petroleum Gas

LTSM - Long-Term Simulation Model

MJ - Megajoule

MN - Manitoba

MW - Megawatt

NB - New Brunswick

NEB - National Energy Board

NF - Newfoundland

NS - Nova Scotia

NT - Northwest Territories

ODt - Oven dried tonnes (of wood)

ON - Ontario

PE - Prince Edward Island

PH - Process Heat (subdivided into PH-I: Intermediate Temperature Process Heat and PH-H: High Temperature Process Heat)

PJ - Petajoule

QU - Quebec

RPP's - Refined Petroleum Products

SEP - Soft Energy Path

SK - Saskatchewan

TJ - Terajoule

YT - Yukon Territory

Conversion Factors

1 GJ = .948 x 10^6 Btu

= 278 kW.h

= .033 tonnes coal (imported bituminous)

= .034 tonnes coal (Canadian bituminous)

= .051 tonnes coal (sub-bituminous)

= .065 tonnes coal (lignite)

= 108 kg (.108 tonnes) peat

= 25.9 Litres (0.026 m^3) crude oil (equal to .163 barrels)

= 24.0 Litres (.024m^3) still gas

= 28.9 Litres (.029m^3) gasoline (equal to 6.35 gallons

= 26.5 Litres (.027m^3) kerosene (equal to 5.84 gallons)

= 25.9 Litres (.026m^3) diesel (equal to 5.69 gallons)

= 25.9 Litres (.026m^3) light fuel oil (equal to 5.69 Imperial gallons)

= 24.0 Litres (.024m^3) heavy fuel oil (equal to 5.27 Imperial gallons)

= 23.6 Litres (.024m^3) petroleum coke

= 29.8 Litres (.030m^3) aviation gasoline (equal to 6.56 Imperial gallons)

= 27.8 Litres (.028m^3) aviation turbo fuel (equal to 6.12 Imperial gallons)

= 26.9 x 10^3 Litres (26.9m^3) natural gas (equal to 950 cubic feet)

= 50.5 kg (.051 tonnes) oven dry wood

= 43.5 kg (.044 tonnes) spent pulping liquor

= 57.2 kg (.057 tonnes) wood product mill waste

= 68.4 kg (.068 tonnes) strav

= 45.2 kg (.045 tonnes) dry manure

= 90.9 kg (.091 tonnes) municipal solid waste

= 63.4 Litres (.063m^3) methanol (equal to 14.0 gallons)

= 47.4 Litres (.047m^3) ethanol (equal to 10.4 gallons)

= 25 kg (.025 tonnes) vegetable oil

= 33.6 to 89.7 x 10^3 Litres (33.6 to 89.7m^3) biogas (equal to 1188 to 3167 cubic feet)

POOR

QUALITY

ORIGINAL